The
# ENGINEERS' DIGEST

*A World Review of*
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 1 JANUARY, 1960

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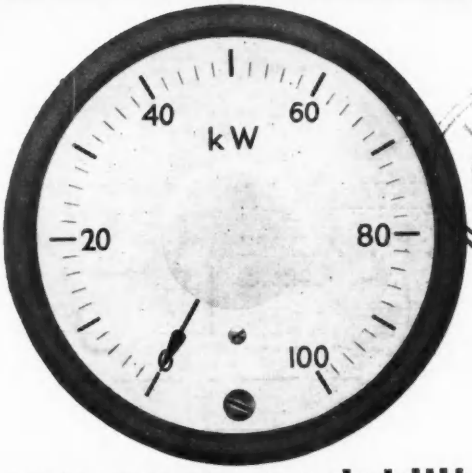


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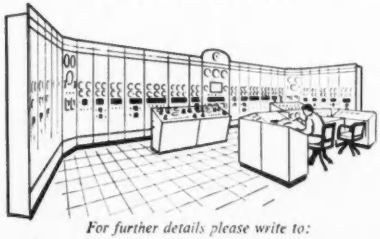

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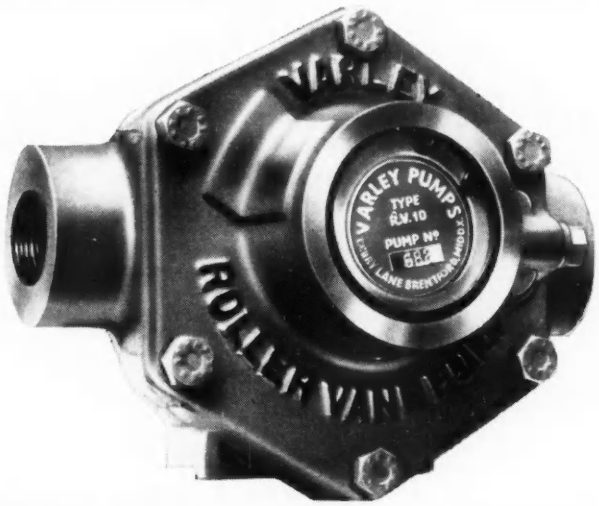


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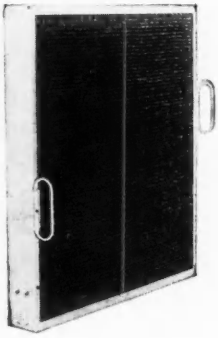

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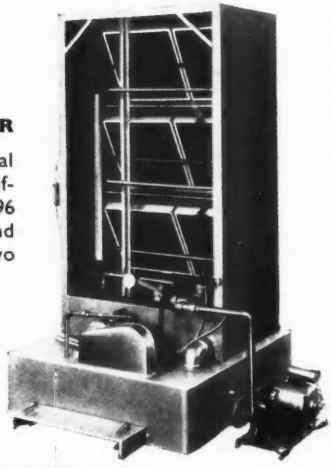

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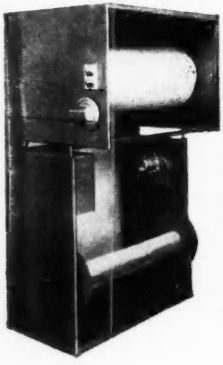

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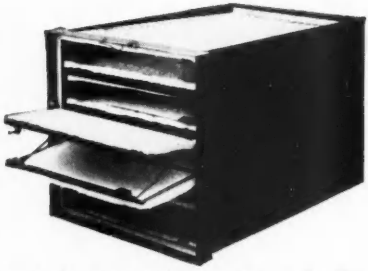

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The ENGINEERS' DIGEST

A World Review of DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 1 JANUARY, 1960

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*Annual Subscription Rates:*
£2 2s. 0d. in the Sterling area, $7.50 in the Dollar area

Printed in Gt. Britain by THE ALCUIN PRESS, Welwyn Garden City, Hertfordshire, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1.



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# The MINIDIGEST

Investigations are being made by Armour & Co., of Chicago, and by Radiation Applications, Inc., of New York, into a technique for **recovering metals from solution by foam separation.** The basis of this technique is that certain soaps, when added to a mineral-containing solution, cause the minerals to rise to the surface when bubbles of gas are blown through the solution. Possible commercial uses of this technique include the separation of cobalt from nickel and the separation of rare earths.

* * *

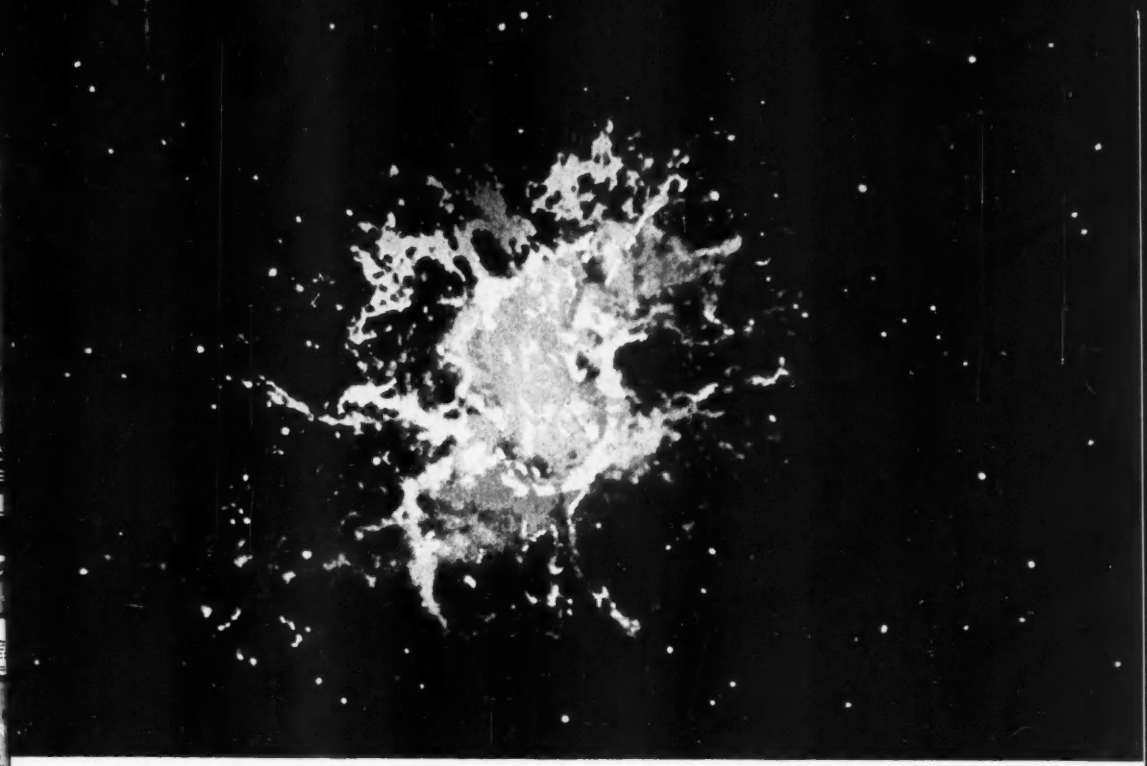
An article in *Mesures & Contrôle Industriel* (November 1959) is concerned with a new type of **thermal diagram for underground power-transmission cables.** As the author points out, the life of a cable is greatly dependent on the thermal conditions to which it is subjected, and the plotting of a thermal diagram is the most convenient and accurate method of studying the temperature rise of cables under variable load. The thermal diagram described makes uses of the elements of the cable itself, and the results of a number of tests are included in the article.

* * *

As reported briefly in *Product Engineering* for December 14, 1959, a **paper which can elongate in all directions** should be promising for improved insulating and laminating materials. This paper, which stems from a stretchable paper first announced about two years ago, is not a crepe paper. Its fibres are compressed and interlocked during processing, so that it will expand, rather than break, under tension. This expansion, which is of the order of 5 to 25% and even higher, gives a considerable spread between yield and tensile strength. The particular advantage of this new type of paper, which is not yet in production, is that the expansion is almost even in all directions, rather than predominantly in one direction, as in the case of the type first introduced. It is stated that it is possible to apply the process to other fibres, e.g., asbestos, providing a non-flaking, flexible high-temperature material.

* * *

In a paper in the *Czechoslovak Journal of Physics* (No. 6, 1959), an **X-ray diffraction method for determining quantitative fibre texture in wires** is described. With this method, the integrated intensity of diffracted rays in a direction parallel to the plane defined by the direct beam and the wire axis is measured, a counter



# WHAT'S COOKING at 5,000 MILLION DEGREES CENTIGRADE?

The answer is simple . . . Iron. It is now generally believed that just as Hydrogen fuses together in the interior of the Hydrogen Bomb to form Helium at the relative coolness of 10 Million degrees, so at the centre of certain massive stars called Super Novae the light elements are built up by fusion to form gold, lead and iron at 5,000 Million degrees. These stars then become unstable and explode violently scattering the metals all over space where they then form new stars and planets.

The scale of the explosion can be appreciated when it is realized that such a star gives out as much light in one second of time as the sun does in a thousand million years.

The above photograph is of such an explosion that took place 900 years ago in the constellation of the Crab.

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## The MINIDIGEST

diffractometer or Weissenberg goniometer being used for measuring the intensities, and, from the measured intensity variation of a certain diffraction line, a quantitative pole figure of the corresponding atomic plane can be plotted, after correcting the intensities for absorption of radiation in the sample. The absorption factor for different orientations of the sample was determined analytically.

* * *

The results of research at the University of California, Los Angeles, indicate that copper oxide is a possible **anti-smog catalyst** for breaking down and eliminating smog-producing gases present in the exhausts of motor vehicles. These gases, i.e., nitric oxide and hydrocarbons, which are both contained in petrol, lose their pollution effects when the nitric oxide content is decomposed by copper oxide to nitrogen and oxygen and when the hydrocarbons are oxidized to carbon dioxide and water.

* * *

As reported in *Werkstoffe und Korrosion* (No. 9, 1959), a method has been developed for the **direct chromium plating of copper, brass, nickel, zinc, or iron.** The method is based on the discovery that, under controlled conditions of current, temperature, and pH-value, chromium can be segregated in a glossy form from complex chromium trisulphate solutions containing urea. It is stated, however, that the thickness of the coatings deposited is limited, because, after a certain thickness has been obtained, cracks or fissures tend to develop.

* * *

According to a brief note in *Materials in Design Engineering* for December 1959, it is reported that **polythene polishing wheels** can drastically reduce the amount of time necessary **for preparing samples for metallurgical examination.** Solid polythene wheels or polythene bonded to metal wheels can be used, the advantages of the material being that it is resilient and resistant to the dilute acid wetting agent used for polishing. With metal wheels, conventional polishing methods usually require wax to protect the wheel against the acid, and excessive time is needed to prepare samples. Thus, in the case of such refractory metals as tantalum and zirconium, polishing often takes as long as 12 hr and even then is not always satisfactory. By contrast, representative polishing times with polythene wheels are only 30 min for tantalum

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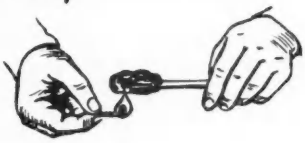

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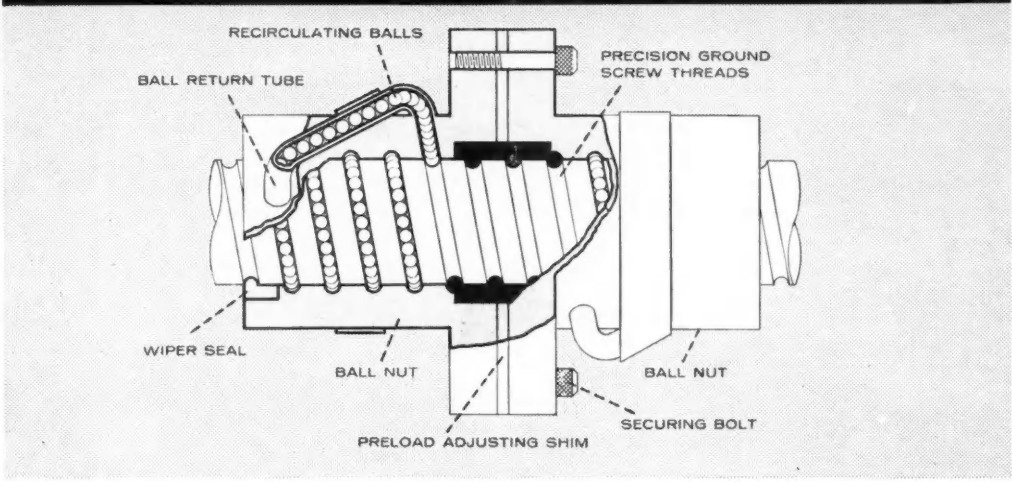


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## The MINIDIGEST

and 5 min for zirconium. Numerous other metals have been successfully polished with polythene wheels, which can be used without modification for specimens of varying hardness.

* * *

It is reported that strain measurements are being obtained at the Battelle Memorial Institute, Columbus, Ohio, by means of two **special strain-gauge techniques,** one of which is used for measurements in equipment immersed in boiling water, and the other for measurements at critical points in closely fitting mechanical parts. To protect the strain gauge for indefinite periods in boiling water, it is housed in a small brass pod, which is soldered to the equipment under test, the wires leading from the pod being enclosed in a stainless-steel sheath. In the technique involving strain-gauge measurements in closely fitted parts, the gauge is placed in a shallow groove cut in one of two mating parts, and then an epoxy resin is used to insulate the gauge and to fill in the groove before assembly.

* * *

A new **process for the gasification of petroleum oil,** developed by the Incandescent Heat Co. Ltd., of Smethwick, Birmingham, is stated to be continuous and does not employ catalysts, cracking heat being supplied by the burning of oil and waste products in a compact and simple furnace setting. The oil to be gasified is injected with steam into a system specially designed to exercise precise and uniform control of cracking temperatures, enabling the production of unwanted by-products to be kept to a minimum. The calorific value of the gas produced, which is interchangeable with natural gas or coal gas of similar calorific value, ranges from 500 to more than 1200 BTU/cu ft.

* * *

Stated to afford better corrosion protection for steel than borosilicate types of glass, an **improved glass coating** announced by Glascote Products Inc., of Cleveland, Ohio, has a wide range of possible applications, including degreaser containers, linings for pipes, tanks, and pumps for hot acids and alkalis, and flue linings. It is claimed that the new material resists spalling when heated to 350°F and then plunged into water at room temperature, whereas borosilicate glass shatters under the same conditions. Furthermore, borosilicate glass is about 400% less resistant to alkalis and about 65% more susceptible to acid erosion than the new product.

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# BUSINESS NOTES

It is announced by **Wayne Kerr Laboratories Limited,** of Chessington, Surrey, that they have established a special section which will concentrate on, or assist in, solving problems relating to industrial and scientific measurements. The new section, which is known as the Applications Group of the Industrial and Electronics Division, will have the support of other sections of Wayne Kerr Laboratories and can be consulted for a strictly advisory service or for the purpose of developing new instruments into a fully engineered form. The administration offices of the Applications Group are at 44 Coombe Road, New Malden, Surrey.

* * *

Involving an expenditure of about £3,000,000, the modernization and expansion programme embarked on three years ago by **The North British Rubber Co. Ltd.** at Castle Mills, Edinburgh, is now almost completed. This programme includes the erection of a major new hose plant, the doubling of the capacity of the tyre plant, and the modernization of remaining facilities and the erection of a new central steam plant. In the new hose plant, machinery is in position and production is gaining momentum. This plant, which comprises a single-storey building of some 100,000 sq ft, produces special types of advanced hose for the oil, aircraft, motor, and hydraulic equipment industries.

* * *

Situated in the smokeless zone on the outskirts of Sheffield and with a site area of nearly 12 acres, the new factory and office premises of **Moore & Wright (Sheffield) Ltd.** were officially opened on December 1, 1959. The new tool factory is one of the largest and most modern factories of its kind in Europe.

* * *

It is announced that **Pantak Ltd.,** of Windsor, Berks., have recently concluded an agreement with **Usines Balteau,** of Liège, Belgium, for the marketing in the U.K. of two ranges of lightweight, portable industrial X-ray equipment. These ranges comprise two oil-insulated units of 140 and 200 kV capacity, and three gas-insulated units of 150, 180, and 300 kV capacity, the 180-kV unit being specially developed for examining circumferential welds, etc.

* * *

**The Birmingham Tool & Gauge Co. Ltd.,** of Birmingham 19, have now secured the sole distribution rights for the range of electromagnetic bench production tools, including electro-punches and electro-tables, manufactured by **Black & Webster Ltd.** in the U.S.A.

* * *

A £1,000,000 British subsidiary, registered as the **J. I. Case Company Limited,** with headquarters in London, has been formed by the **J. I. Case Company of America,** one of the world's leading manufacturers of tractors and earth-moving equipment. The new British company will not only be responsible for manufacture, sales, and distribution in the U.K., but also for sales to Europe, the Middle East, India, Pakistan, Africa, and other Commonwealth countries.

* * *

It is announced that **Brakeshoe International, S.A.,** a wholly owned Swiss subsidiary of the **American Brake Shoe Company,** of New York, has acquired industrial hydraulics firms in England and Belgium. The British acquisition is **Deri (Engineers) Ltd.,** manufacturers of


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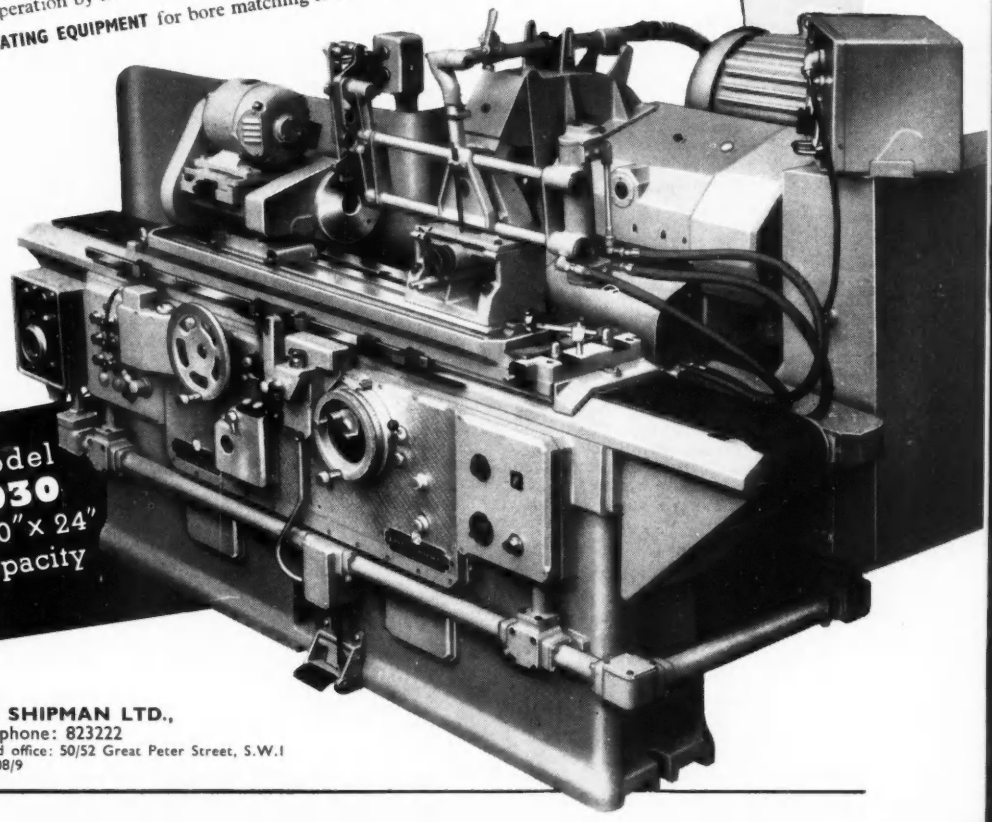

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# BUSINESS NOTES

industrial hydraulic pumps and motors, and hydraulic transmissions and liquid fuel pumps for special applications. The Belgian acquisition is **Hydrobel, S.A.,** who design and install industrial hydraulic and pneumatic systems and who manufacture specialized hydraulic equipment. Both firms will continue to manufacture their own products, but will also manufacture in Europe the range of Denison hydraulic pumps, motors, presses, and controls made by the American Brake Shoe Co.

* * *

It is announced by **Associated British Machine Tool Makers Ltd.,** of London, S.W.1, that the **Lapointe Machine Company** has been formed as a subsidiary to **The Lapointe Machine Tool Company,** of Hudson, Mass., to sell and service ABMTM machine tools in the U.S.A.

* * *

**Henry Beakbane (Fortox) Ltd.** announce that they have now centralized their production in Stourport-on-Severn and have closed their London factory. All technical and sales enquiries in the London area are now being dealt with at their new office at 28–30 Little Russell Street, London, W.C.1. (Tel.: HOLborn 7295).

* * *

A permanent headquarters for group research at Maple Cross, Rickmansworth, Herts., is to be established by **The Cementation Group of Companies.** Costing about £80,000, the new research centre will house a staff of about fifty and will consist of offices and laboratories on two floors, with a total area of 18,000 sq ft. In addition to its research activities, the centre will accommodate the laboratories of the Group's soil-mechanics section.

* * *

A £2,000,000 expansion scheme for **Shepcote Lane Rolling Mills Ltd.,** of Sheffield, which is owned jointly by **Firth-Vickers Stainless Steels Ltd.** and **Samuel Fox & Co. Ltd.,** has been approved by the British Iron and Steel Board and the British Iron and Steel Federation. The new production facilities, which are expected to be in operation by the second half of 1961, will be mainly for stainless-steel wide strip in coil form.

* * *

**Electronic Associates Inc.,** of Long Branch, N.J., U.S.A, manufacturers of precision analogue computing equipment, announce the formation of a new British company, **Electronic Associates Ltd.,** with head offices and works at Victoria Road, Burgess Hill, Sussex, where manufacture of the well-known 231-R analogue computer is now starting.

* * *

**Premier Bitumen & Asphalte Co. (1959) Limited,** of Western Road, Bracknell, Yorks., has been formed within the **Expandite Group** for the purpose of manufacturing and marketing a range of bitumen compounds and other specialized products used in the building and civil-engineering industries.

* * *

Coinciding with the final reorganization of the structure of the parent company, **Associated Electrical Industries Limited,** into several product divisions, **Birlec Limited,** of Erdington, Birmingham, announce that the company's name has now been changed to **A.E.I.-Birlec Limited.** The internal organization of the company remains unchanged.


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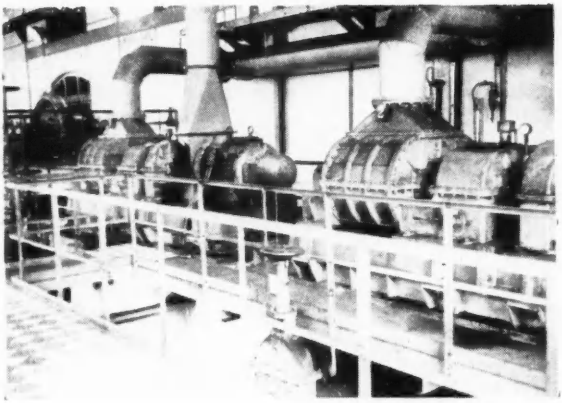

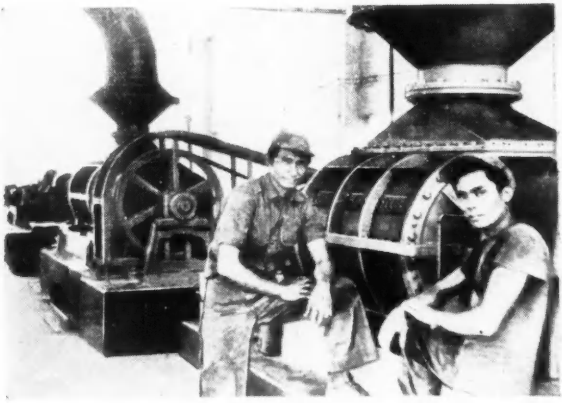

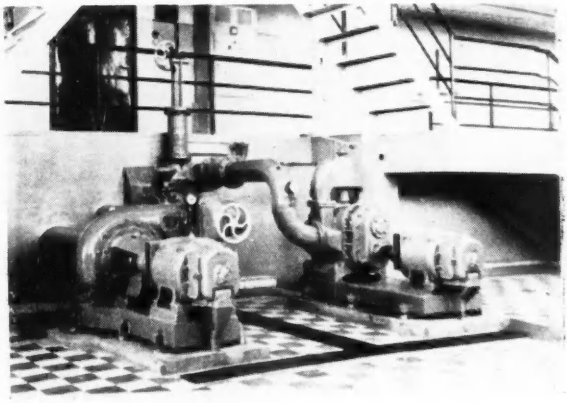

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◀ P I T ▶ 1.158 - 9/58

# PERSONAL

**Mr. F. W. H. Shaw, A.M.B.I.M.** has been appointed managing director of Submarine Cables Limited, of London, W.C.1, in succession to **Mr. F. S. H. Lemon,** who has retired after 40 years' service.

* * *

**Mr. C. T. M. Bagnall,** who has been publicity manager with the English Electric Company Limited since 1952, has been appointed manager of publicity and information services. The new position carries responsibility for both the company's public-relations and publicity departments, and follows the recent retirement of **Mr. J. I. Hall** as the company's public-relations officer.

* * *

**Mr. E. C. Fox,** general manager of the English Electric Company in India, was appointed managing director of the English Electric Company of Australia (Pty.) Ltd., in January 1960, in succession to **Mr. C. W. Goodman,** who has retired but continues full-time service as chairman of the Australian company. In India, **Mr. N. P. Dingwall,** former manager of the company's Calcutta office, has replaced Mr. Fox as general manager.

* * *

With the development of Kelvin marine engines, the Bergius Company Limited, of Glasgow, announce the appointment of **Mr. A. M. Mackay, A.M.I.Plant E.,** as service manager, and **Mr. Bruce P. Guard** as London representative, with offices at 37/41 Bedford Row, London, W.C.1.

* * *

**Mr. E. Masters,** director of the Fighting Vehicles Research and Development Establishment at the Ministry of Supply, was appointed managing director of Petters Limited and Hawker Siddeley (Hamble) Limited, on January 1, 1960, and also becomes a member of the board of Hawker Siddeley Industries Limited. Mr. Masters succeeds **Mr. D. K. Fraser,** who has resigned his directorships with the various Hawker Siddeley Group after being appointed a joint managing director of G. A. Harvey & Co. (London).

* * *

**Dr. W. G. Hiscock, B.Sc., Ph.D., F.R.I.C., F.B.I.M.,** has been appointed chairman of the Lead Development Association for 1960.

* * *

**Mr. W. S. Richards** has been appointed managing director of Brightside Heating and Engineering Co. Ltd., of which he has been a director for some years. **Mr. J. R. Nuttall** has been appointed secretary of Brightside Engineering Holdings Ltd., following the resignation of **Mr. R. I. Slater,** after the latter's appointment as managing director of Moorwoods Ltd.

* * *

It is announced that **Mr. B. Rosen** has been appointed managing director of Sandvik Swedish Steels Ltd., of Halesowen, Birmingham, in succession to **Mr. O. Grundberg,** who has been managing director since 1947 and who has left to take up another appointment.

* * *

Elcontrol Limited, of Hitchin, Herts., announce that **Mr. B. A. Worswick, B.Sc.(Hons.), A.Inst.P.,** has been appointed technical director with a seat on the Board.


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# CONTRACTS

J. G. Statter & Co. Ltd., a member of the Lancashire Dynamo Group, have been awarded a further contract by the Goverment of Kuwait Electricity Department for the supply of high-voltage metal-clad switchgear of 11-kV, 350-MVA rupturing capacity, for the purpose of extending their distribution system. The new £175,000 contract follows a similar contract, placed some 18 months ago with the same company for switchgear.

* * *

Following a recent order for a second sinter plant to be installed at Aviles in Spain, Head Wrightson Iron & Steel Works Engineering Ltd., a subsidiary of Head Wrightson & Co. Ltd., of Thornaby-on-Tees, are now engaged on the building of an iron-ore sintering plant at the Clyde Iron Works, Glasgow, of Colvilles Ltd. The plant will be one of the largest single-strand sintering units to be built in Great Britain and will be capable of producing 2500 tons of blast-furnace sinter per day. The total value of the order is approximately £700,000. The plant is expected to be commissioned by about the middle of 1961 and is the second of this type which Head Wrightson have supplied to Colvilles Ltd. in recent years.

* * *

The John Thompson Water Tube Boilers Company, of Wolverhampton, have received from the Central Electricity Generating Board a letter of intent to place a contract, valued at approximately £6,000,000, for the supply of two water-tube boilers and their accessories for two 350-MW units at the Drakelow " C " power station in Derbyshire. Of 2,450,000 lb/hr evaporation, each boiler will have a reheat temperature of 1055° F, a final steam temperature of 1055° F, and a working pressure of 2400 psi. These boilers, which will be coal-fired, are among the largest single units yet ordered by the Central Electricity Generating Board.

* * *

Two important contracts have recently been awarded to member companies of the Power-Gas Group. Thus, Ashmore, Benson, Pease & Co. Ltd., of Stockton-on-Tees, have received a contract valued at about £4,000,000 for the design, manufacture, and erection of two complete blast-furnaces for Richard, Thomas & Baldwins Limited. These furnaces, each with a hearth diameter of 30 ft, will be installed at Spencer Works, Monmouthshire, to provide iron for the company's new integrated steelworks and strip mill.

The second contract has been negotiated between P.G. Engineering Ltd., of Stockton-on-Tees, and V/O Techmashimport, of Moscow, for the complete supply of a plant for the production of polystyrene, with a rated capacity of 5000 tons per year. The value of the contract is approximately £650,000, and delivery is scheduled to commence in 1960. The process design is to be supplied by BX Plastics Ltd., of Manningtree, Essex, who have recently installed a new unit of this type.

* * *

It is announced by Birwelco Limited, of Aston, Birmingham, that they have been awarded a contract for the supply of seven " Petro-Chem Iso-Flow " furnaces for the new Esso refinery at Milford Haven. The total value of the order is over £300,000. One of the furnaces is for the hydrofiner train and is of the all-radiant type, with a duty of about 55,000,000 BTU/hr. The other six furnaces are for the powerformer unit and have a total duty in excess of 300,000,000 BTU/hr.


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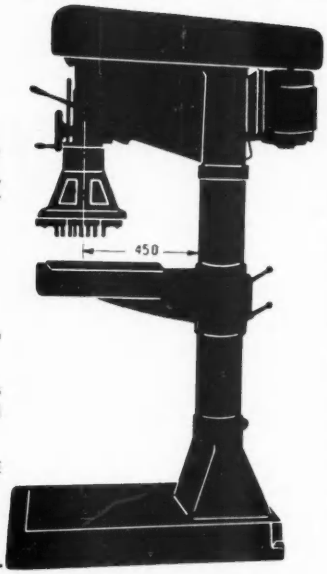


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*See Catalogue of sizes SD58 (available on request).

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SM131

# NEWS ROUND-UP

## Modernization of a Semi-Continuous Bar Mill

Steel, Peech and Tozer, a branch of the United Steel Companies, Limited, are to spend over £400,000 on the modernization of their semi-continuous bar mill, which was laid down nearly 40 years ago and which at present has a drive through line shafting and gearing from a single 3000-hp variable-speed a.c. motor. In order to introduce greater flexibility in the operation of the mill, it is planned to replace this drive with a number of separate variable-speed d.c. motors, totalling 3400 hp, and to renew some of the rolling-mill stands.

The first stand on the present mill is a pinch-roll stand, which is to be replaced by a modern 18-in. horizontal-roll stand. The first two stands of the roughing section of the mill are also to be replaced by new 18-in. horizontal and vertical stands respectively. The horizontal stands will be powered by a single 350-hp d.c. motor, and the vertical stand will be equipped with a 250-hp d.c. motor. A series of paired drives is to be installed on the remaining mill stands. Thus, stands Nos. 3 and 4 will be driven by a 600-hp d.c. motor, Nos. 5 and 6 by a 700-hp d.c. motor, Nos. 7 and 9 by a 750-hp d.c. motor, and Nos. 8 and 10 by a 750-hp d.c. motor. A new motor room is to be built to house all these drives, which will be supplied from 2200 kW of grid-controlled rectifiers.

Other features of the modernization scheme include the installation of a flying shear after No. 6 roughing stand, the provision of a modern oil-lubrication system throughout the mill, and the installation of a high-pressure water system for billet descaling, making it possible to improve the surface condition of the rolled bars, particularly in the case of material destined for bright drawing.

## Epoxy-Resin Dies for Drawing Automobile Parts

According to a report from Ren Plastics, Inc., of Lansing, Mich., it is stated that the Checkers Motors Corporation, of Kalamazoo, Mich., are finding dies based on epoxy resins to be an effective means of drawing automobile parts. In fact, this company, which manufactures taxi-cabs and has just introduced a low-price passenger car, has drawn ten major body panels with epoxy dies and states that as many as 18,000 parts have been drawn with a single die of this type. Nevertheless, it is believed that, impressive as this figure undoubtedly is, there is actually no theoretical limit to the number of draws possible with an epoxy-resin die, provided that down-time is available for repairing and overhauling.

Among the advantages cited for these dies are savings in cost and labour and easier draws, as compared with steel dies. Thus, epoxy-resin dies can be cast off a master in the desired shape relatively simply and economically, using only elementary hand-tools to place and shape the plastic on the master, and the entire job can be carried out in practically any location in the plant because of its simplicity and the elimination of any requirement for special machinery. Furthermore, spotting time is reduced and, when areas needing attention are found, the epoxy resin can be easily and quickly removed or added to form the desired shape, while its flexibility facilitates repairs on edges.

Mainly because of the distribution factor, it is claimed that it is 40% easier to make a draw with epoxy-resin dies than with steel dies. Less spot strain occurs in a steel panel drawn with an epoxy die because of insulating factors and the ability to incorporate slip fillers in the plastic material. Thus, for example, by using an epoxy die, the company is able to include a spare-wheel well in the floor-pan proper. This well, and numerous sharp break lines and curves, can be drawn in the floor-pan because of the completely even distribution of metal on the epoxy die, the wear factor being about the same as with the cast-iron dies originally used.

As epoxy resins are not as strong as metallic dies, down-time must be available for possible repairs, as already mentioned. The epoxy resin actually serves as a binder for the filler, from which the strength is derived, fillers being selected according to the specific application of the particular die. For instance, fillers used by the company include iron and steel powders, iron oxide, glass fibres, carbon, and calcium carbonate. Thus, the die used to draw fenders has, among other fillers, iron and steel powders, while the floor-pan dies use glass fibres, iron oxide, and calcium carbonate, and the wheel-house and hood-hinge dies are reinforced with iron and steel powders as fillers.

## Reciprocal British and Soviet Trade Fairs

An agreement regarding the holding of reciprocal exhibitions of British and Soviet trade and industry in Moscow and London respectively has recently been signed in London by Mr. M. V. Nesterov, President of the All-Union Chamber of Commerce of the U.S.S.R., Mr. V. G. Sherren, managing director of Industrial and Trade Fairs Limited, who are organizers of the British exhibition, and Mr. F. Bower, President of the Association of British Chambers of Commerce.

The Soviet exhibition, which will occupy about 250,000 sq ft, will be held at Earl's Court, London between July 7 and July 29, 1961, and is expected to include


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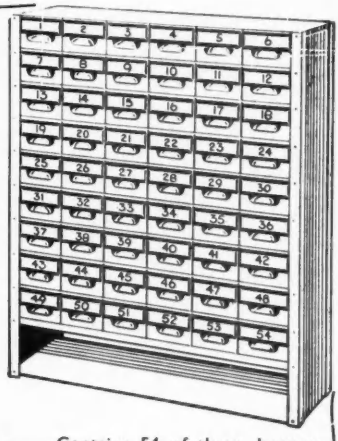

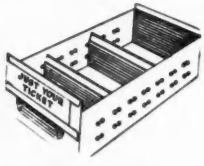

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both capital and consumer goods. The most comprehensive range of Russian machinery and other equipment for the engineering industry ever to have been seen in the U.K. will be on display, and there will also be features depicting achievements in Soviet industry, science, and technology.

The British exhibition, which is expected to occupy a similar area of about 250,000 sq ft, will be held between May 19 and June 4, 1961 in the Sokolniki Park of Culture and Rest, Moscow, and will make use of the Glass and Dome pavilions erected for the American exhibition in Moscow in 1959. However, as the scale of response to this project from British industry has been so great, the covered space required will be considerably greater than that occupied by the American exhibition, so that temporary structures will also be erected on the Moscow site. British exhibits will mainly be confined to a representative display of products in major industrial groups, such as machine tools, textiles and textile machinery, electrical and electronic equipment, chemicals, footwear, and various other groups in which the Russians have shown particular interest.

## Conference on Solid-State Microwave Amplifiers

The Institute of Physics announces that its Electronics Group, in conjunction with the Radio Spectroscopy Group, has arranged a conference on "Solid-State Microwave Amplifiers", to take place at the University of Nottingham between April 6 and 8, 1960. The subjects covered include masers, parametric amplifiers, and related resonance studies.

If required, accommodation will be available in one of the University halls of residence. Further particulars and application forms can be obtained from The Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

## The 1960 Leipzig Spring Fair

The Leipzig Spring Fair, to be held between February 28 and March 8, 1960, will have an exhibition area covering more than 3,000,000 sq ft, and about 9500 exhibitors from some 50 countries are expected to be represented. The exhibition covers all branches of mechanical engineering, instrument making, electrical engineering, precision mechanics, metallurgy, chemicals, etc.

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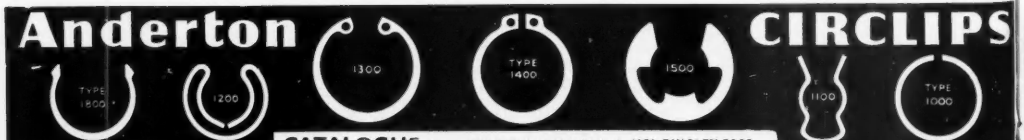


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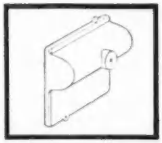

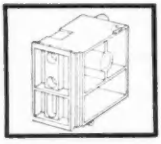

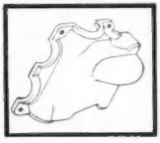

*60 amp. Input Junction Box moulded by Aldridge Plastics Ltd. for Siemens Edison Swan. The four moulded components are shown in the inset drawings.*

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## NEW TECHNICAL BOOKS

**Process Integration and Instrumentation.** 224 pp., 141 illustrations. Published by the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Price: 8/6 (postage, 6*d*.).

Although several books on instrumentation, control, and automation have recently been published, few of them have dealt with the necessary units of equipment which together allow various degrees of automatic operation to be achieved. This well-produced and illustrated book, No. 8 in the Association's *Electricity and Productivity Series*, admirably fills the gap. Essentially, it has been written with the requirements of industrial managers and production executives in mind, but it is also of value to all industrialists and should make a contribution to the improvement of electrical load factor.

The book shows that the steps which lead from detection and measurement to indication, to recording, and eventually to automatic control are intricate and impinge on a wide range of specialized skills. Thus, chemistry, physics, and electrical, mechanical, electronic, and nucleonic engineering are all involved, and the book outlines in simple form the means by which the variables occurring in manufacture can be sensed, measured, and controlled with the ultimate aim of achieving a more completely and perfectly integrated process, including sensing devices, instruments and instrumentation, electronic equipment, actuators, and servomotors, as well as numerous example of methods of automatic operation.

**Engineering Mechanics.** By Dwight F. Gunder and Derald A. Stuart. 402 pp., 140 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 62/–.

Providing a clear transition between the classical approach to engineering mechanics and the newer vector treatment, this excellent book is based on the authors' experience that students find the subject of mechanics easier and more comprehensible in the vector notation and benefit in their later courses by a knowledge of this notation.

Drs. Gunder and Stuart have an informal and lucid style of writing and the ability to make their subject clear and simple. Drawing on a background in elementary physics and mathematics on the part of the reader, the section on statics makes consistent use of the concept of a *fixed* vector, because the authors feel that this approach best meets certain restricting requirements of this part of engineering mechanics. In addition, they introduce new problems to point out the application of mechanics in a wide variety of classical and modern technological fields. However, whether the problems are old or new, their solution by vector methods illustrates their value in simple, as well as complex, engineering problems.

**Electronics.** (2nd Edition, 1959). By A. T. Starr, M.A., Ph.D., M.I.E.E. 438 pp., 380 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 35/–.

Specially written to cover the requirements of the syllabus for the subject of Electronics in the University of London B.Sc. engineering degree, this well-known and authoritative book is also of value to students taking other courses at this level and professional examinations such as those of the I.E.E. and the British Institution of Radio Engineers.

The physical and mathematical aspects of electronics have been stressed, and appendices are included on a.c. theory, Fourier analysis, operational calculus, etc. This second edition has been revised and brought up to date. As such, it includes more detailed descriptions of semiconductors and transistors in the light of recent advances, together with brief references to high-frequency valves such as the klystron and the travelling-wave tube. In addition, a number of recent examination questions have been included.

**Angus Gear Book.** 188 pp., 72 illustrations. Published by George Angus & Co. Ltd., Prince Consort Road, Hebburn-on-Tyne. Price 15/– (7/6 to engineering students).

Although gears are undoubtedly a compact and efficient means of transmitting power, and few machines and mechanical appliances do not contain them in one form or another, their design is a specialized subject. This excellent and well-produced reference book therefore contains a mass of useful information for all those who are concerned with gears and their applications, written and compiled with the object of providing factual details of all aspects of gears and gear-cutting. At the same time, its simple, straightforward, and clear-cut approach to the subject makes it especially useful as a textbook for engineering students.

**Our Mineral Resources.** By Charles M. Riley. 348 pp., 102 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Limited, 37 Essex Street, London, W.C.2. Price: 56/–.

Fundamentally an elementary textbook in economic geology, this excellent work presents, with a minimum of scientific terminology, a wealth of scientific theory and useful facts. At the same time, Dr. Riley has the ability to write simply and interestingly, so much so that this book, in conjunction with its carefully selected illustrations, will surely be appreciated even by those who are not fundamentally concerned with his subject.

Summarizing the most modern knowledge of where and how the valuable mineral resources of the earth are formed by nature, the book also discusses a number of new deposits and offers some non-geological background material, such as the technological uses of minerals, prospecting methods, and world production, providing an appreciation of minerals and their importance to man.


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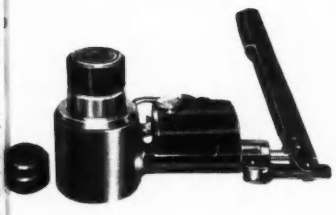

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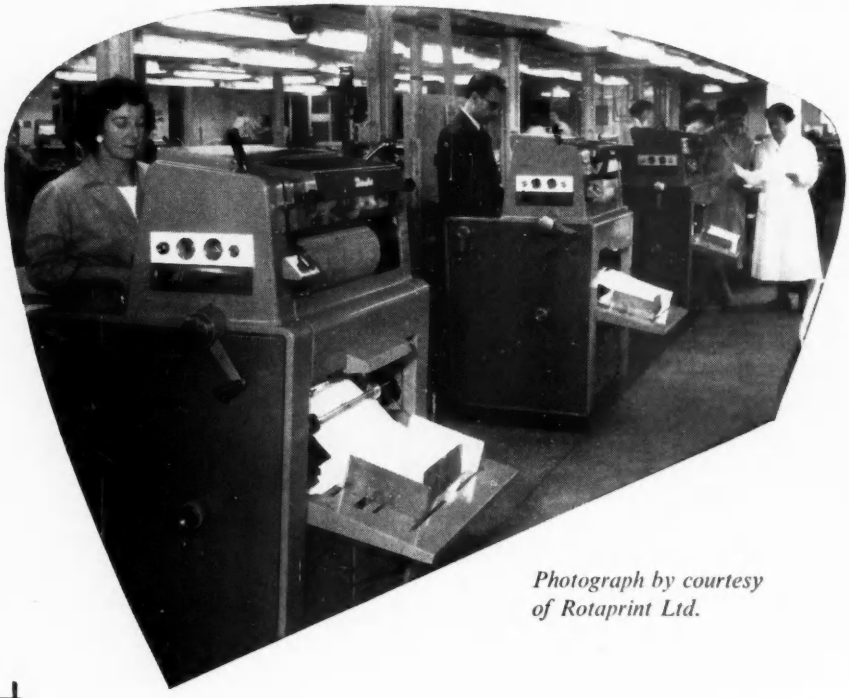

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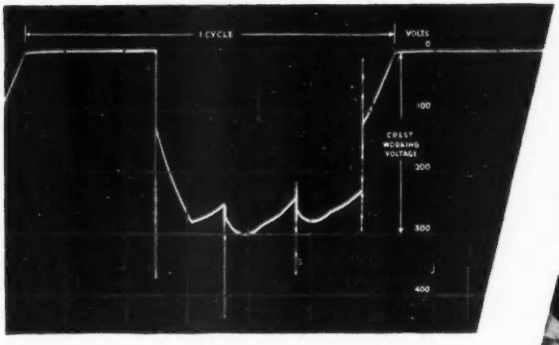

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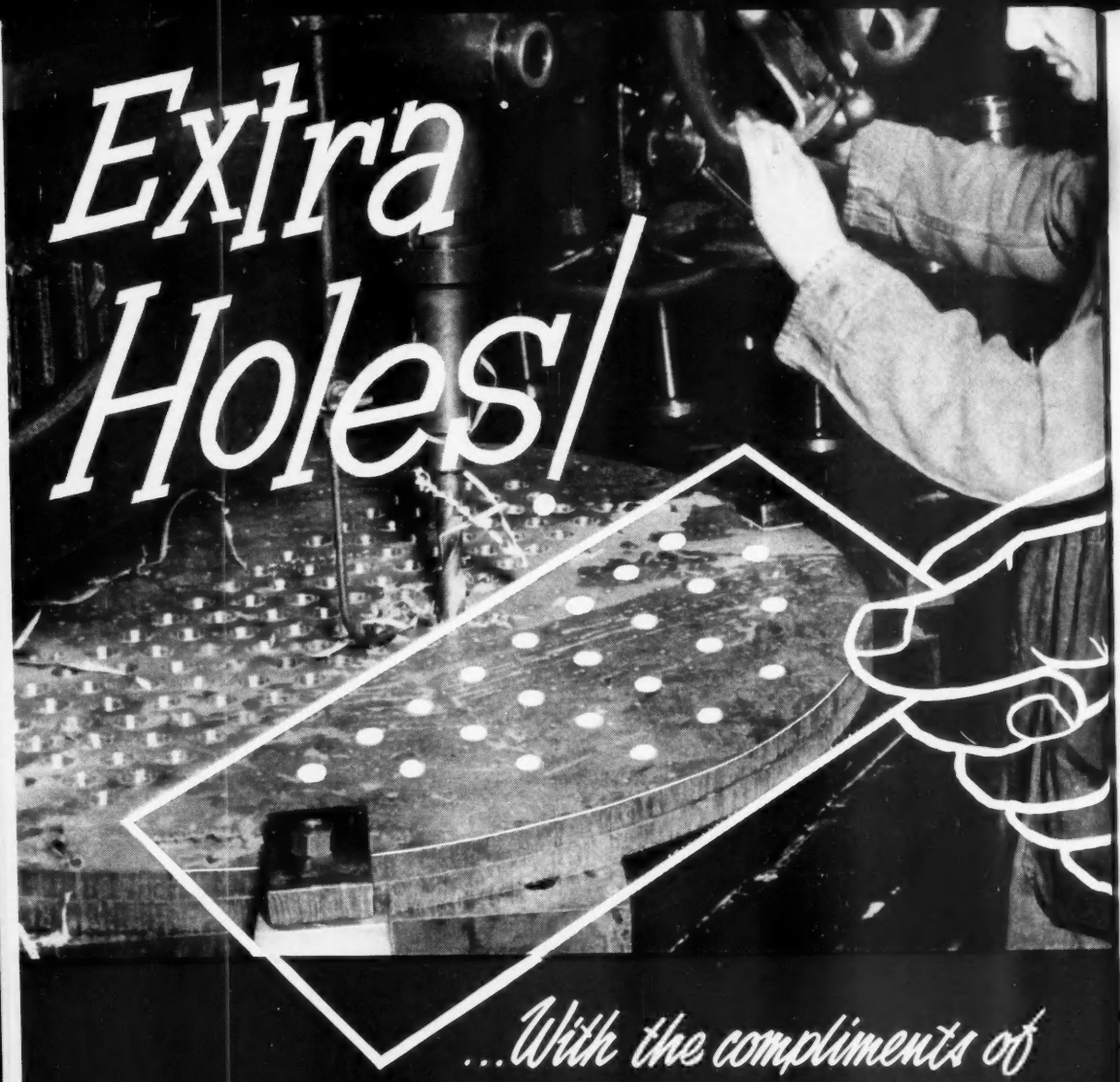


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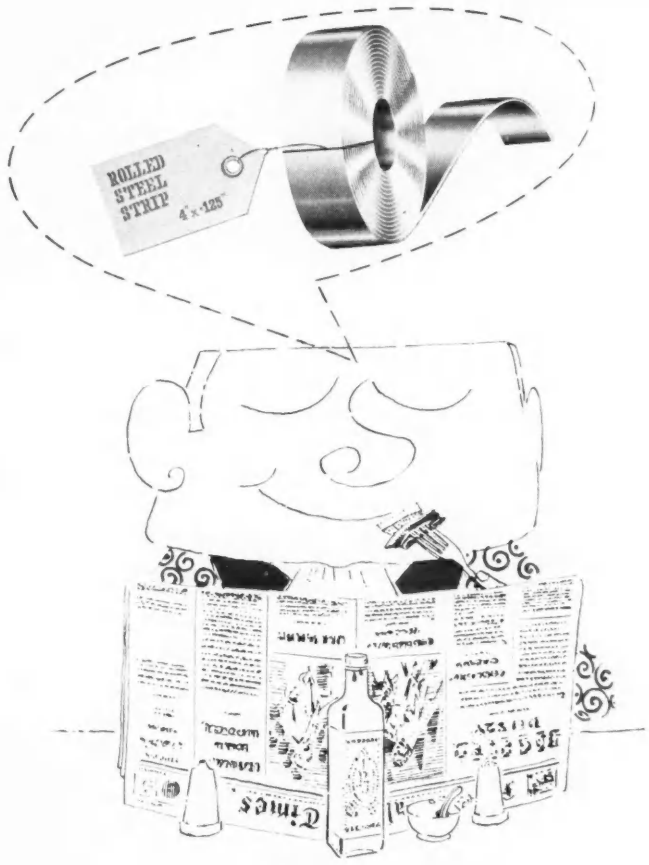


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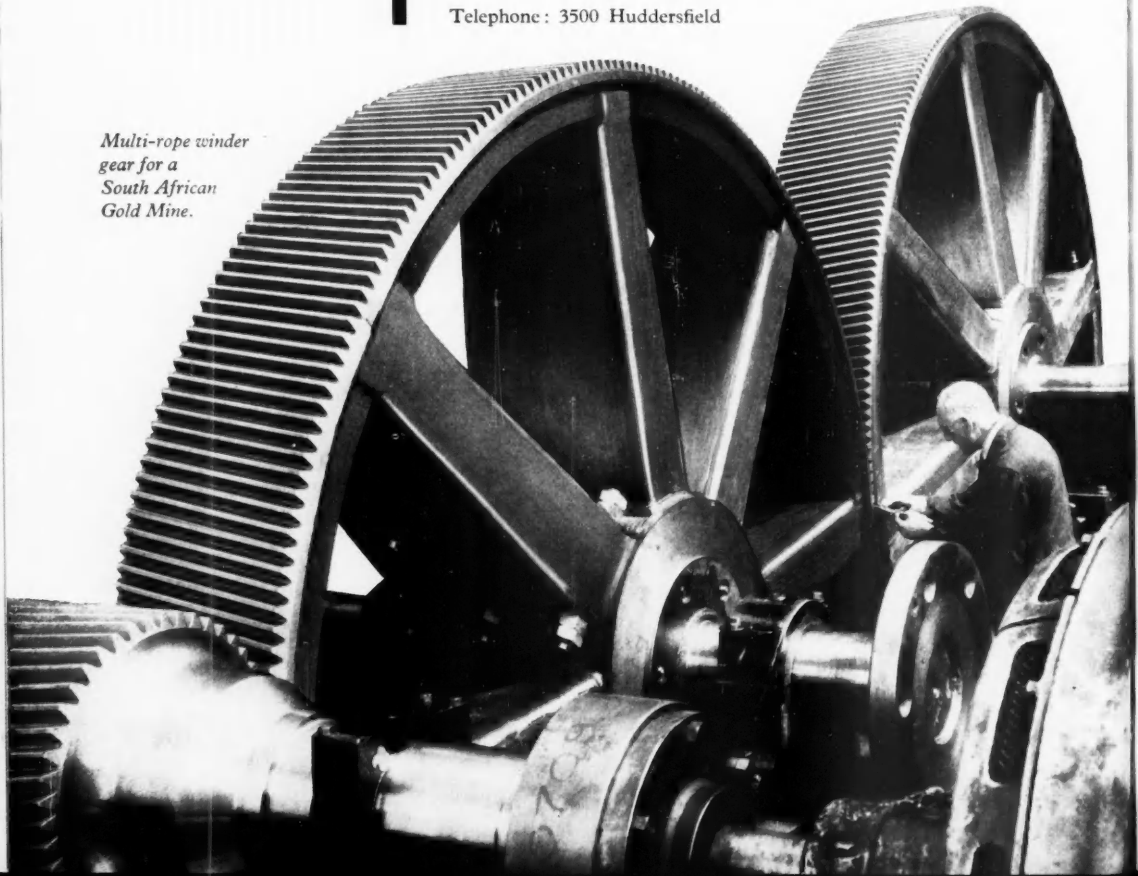

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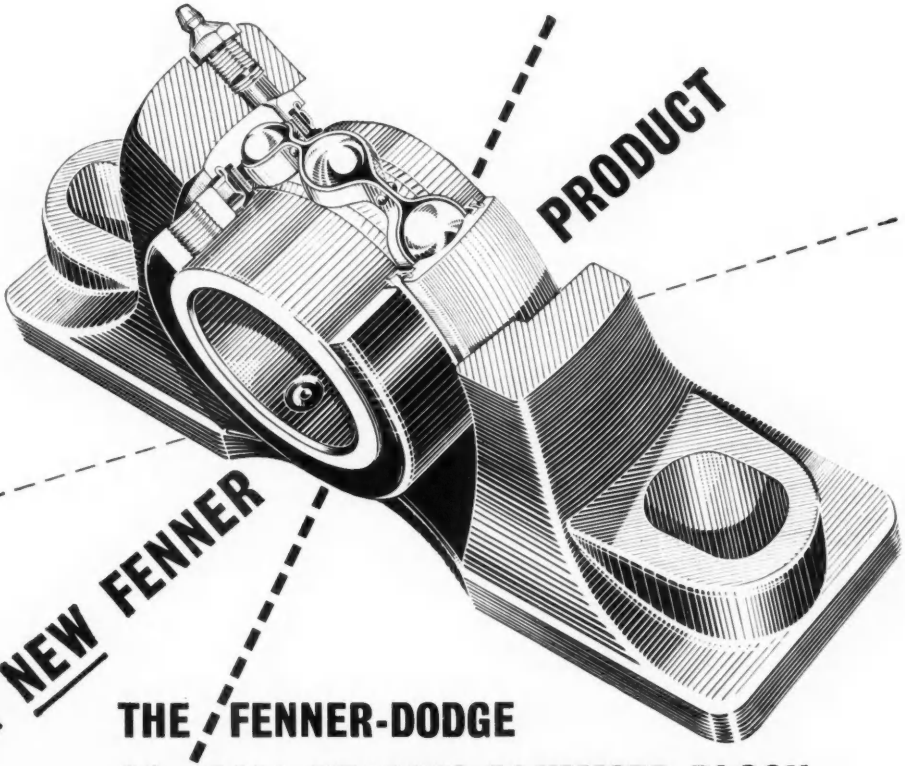

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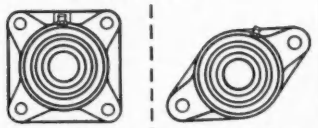

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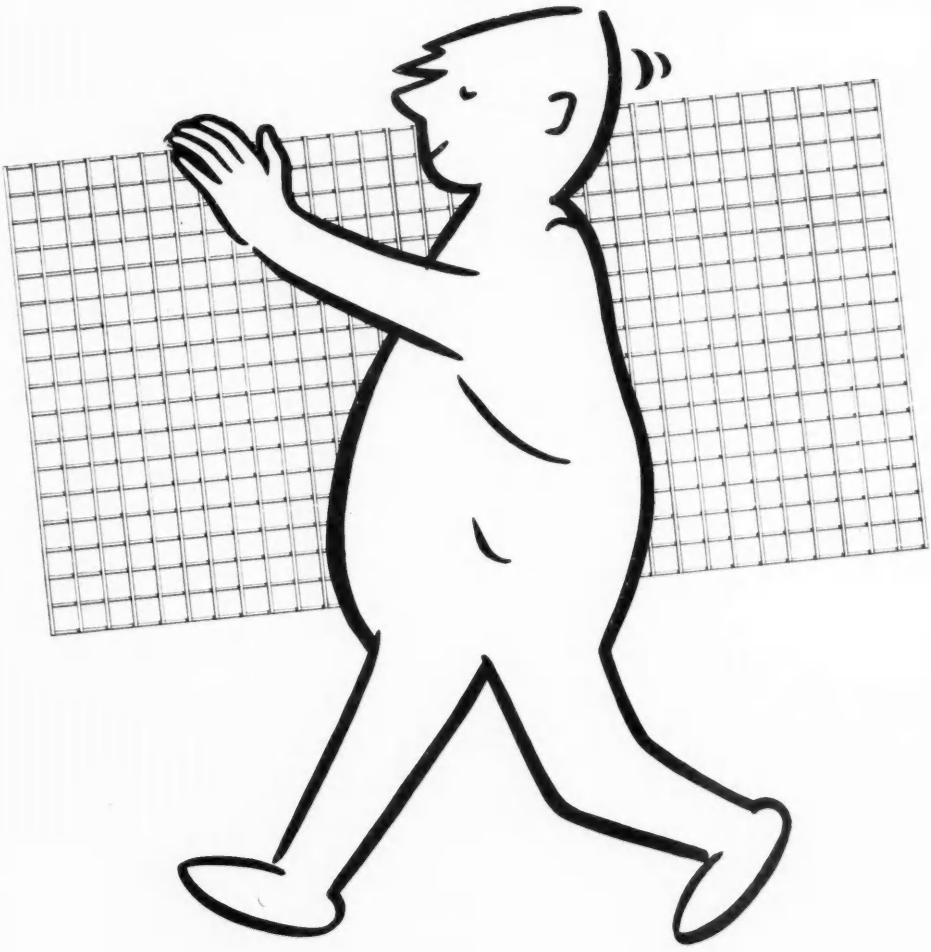

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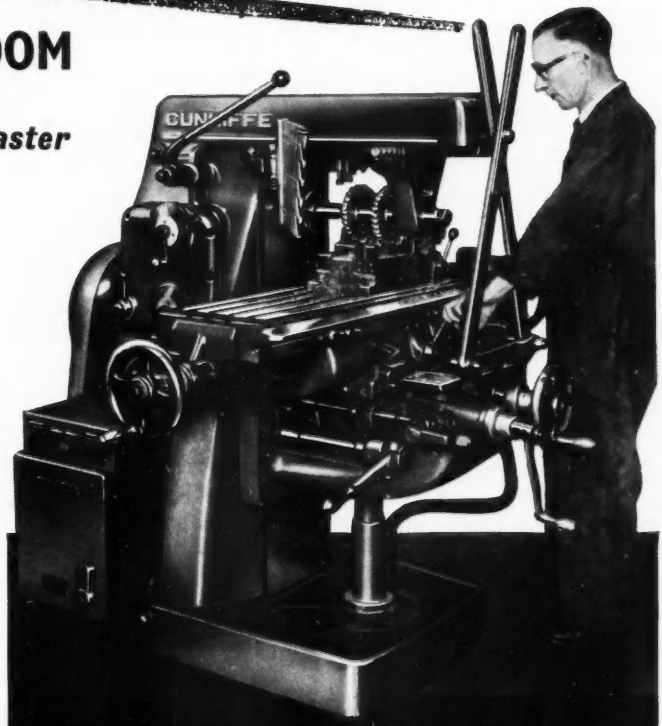

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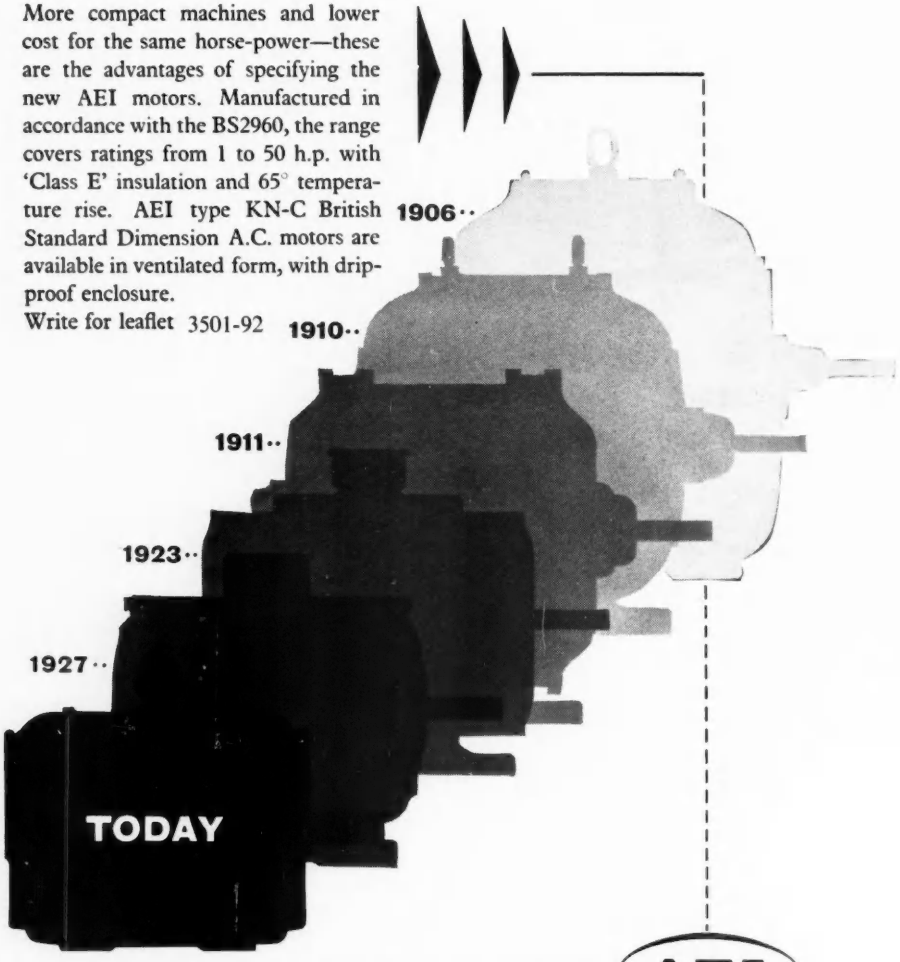


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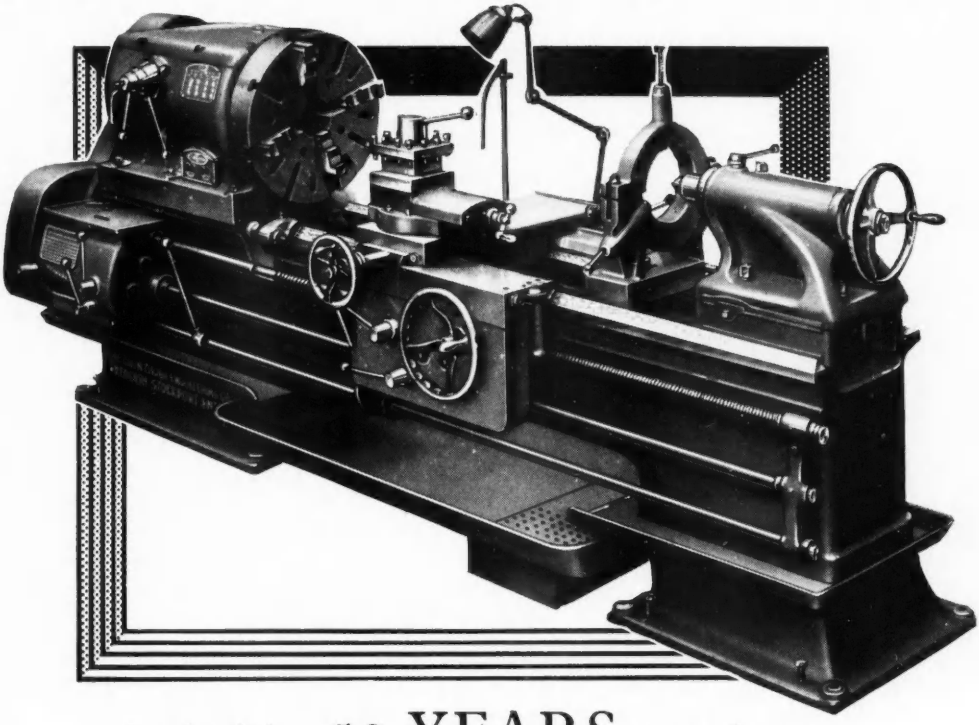

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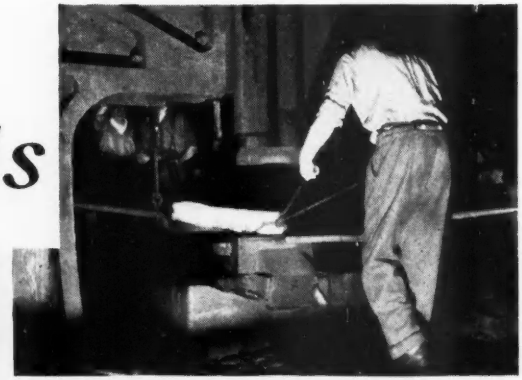

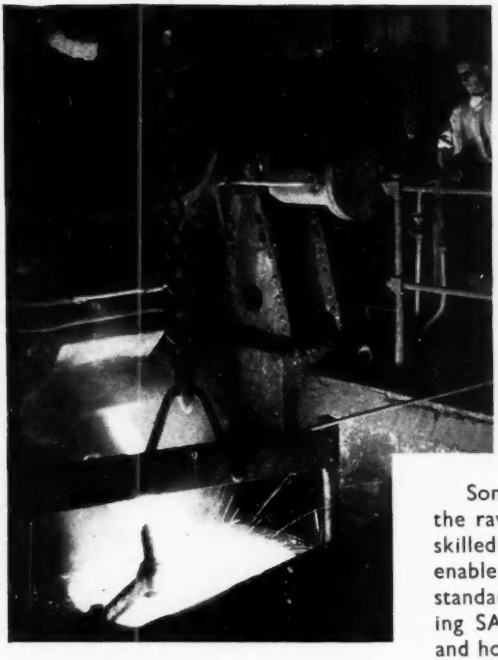

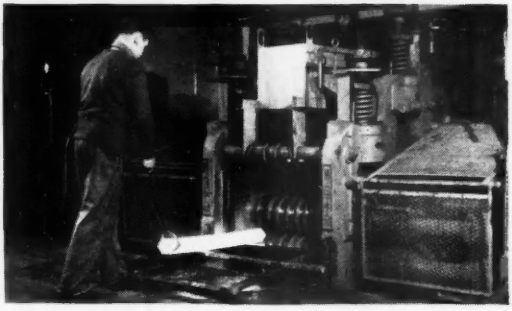

*Booklet B.15 summarises main brands of tool steels. Copy on application.*

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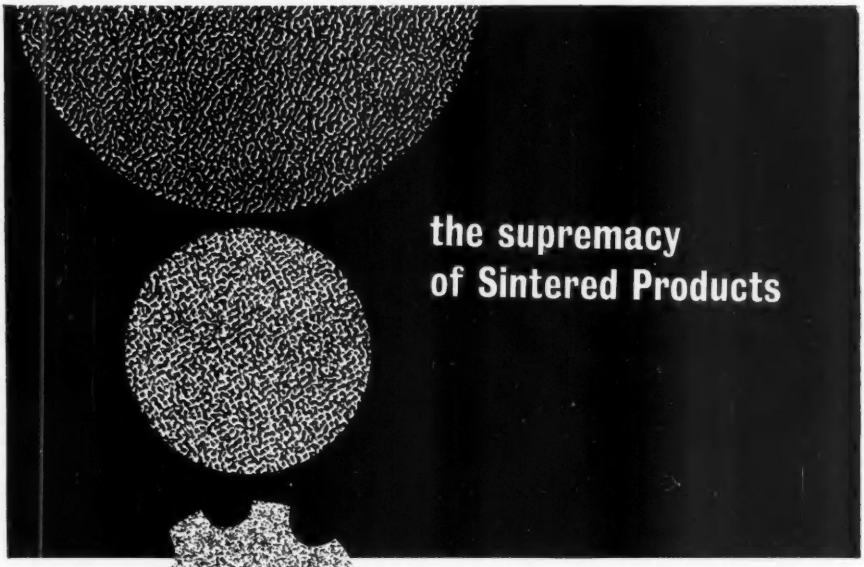


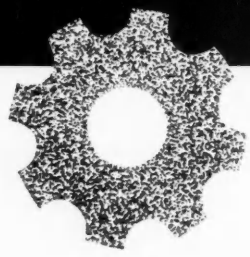

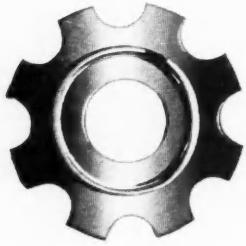

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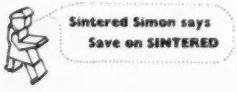


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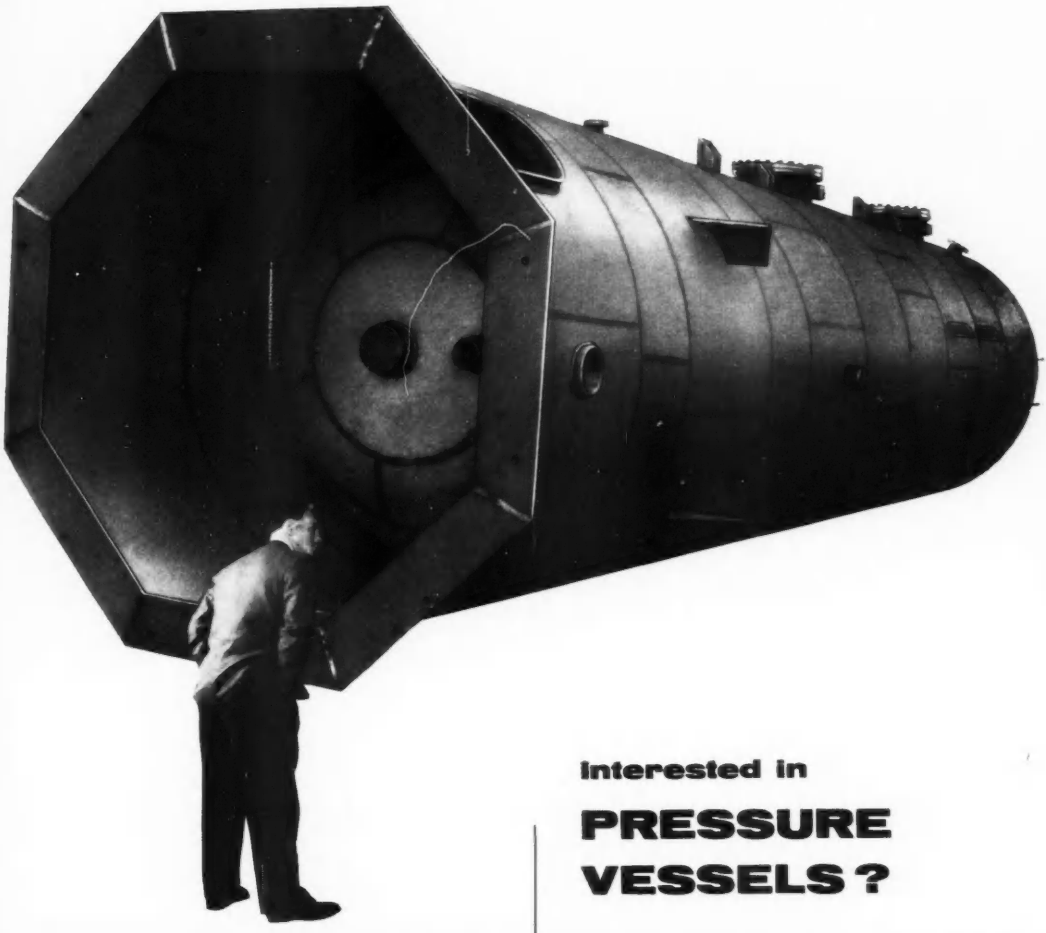

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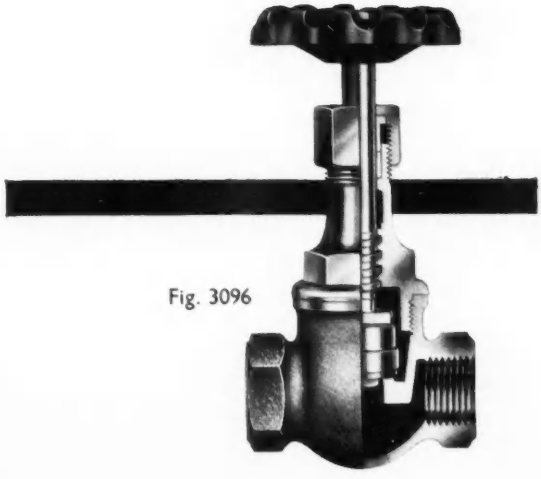
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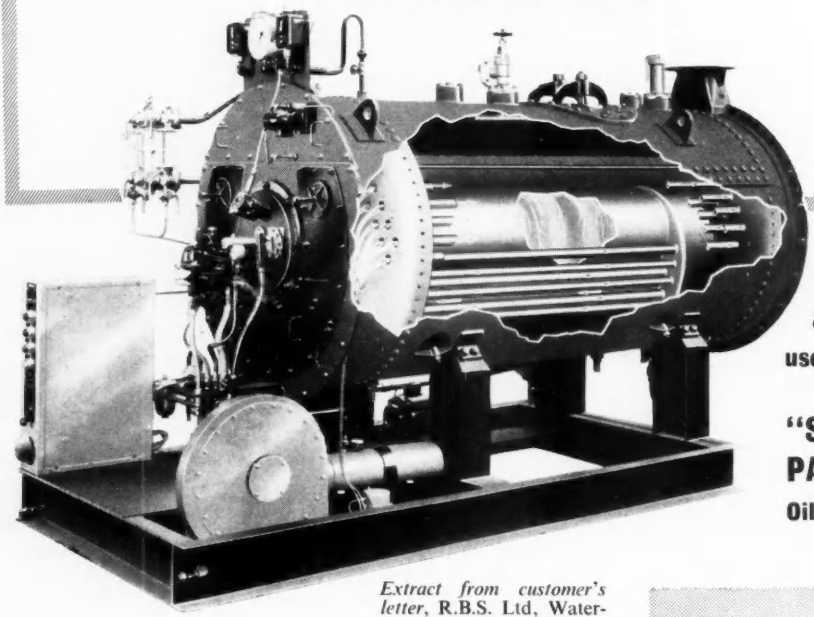

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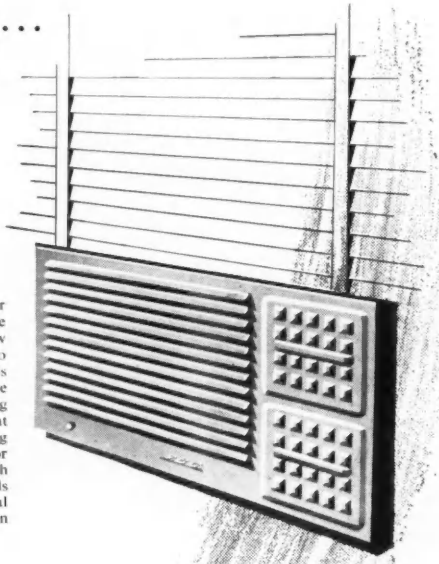

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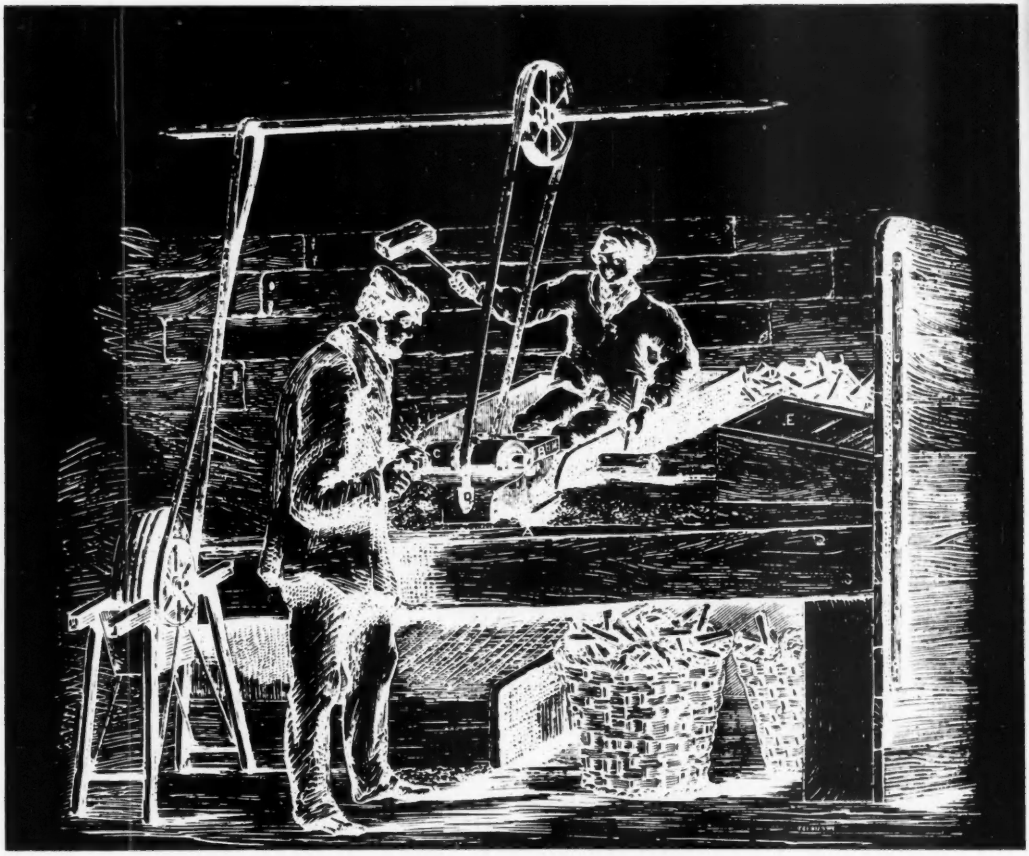

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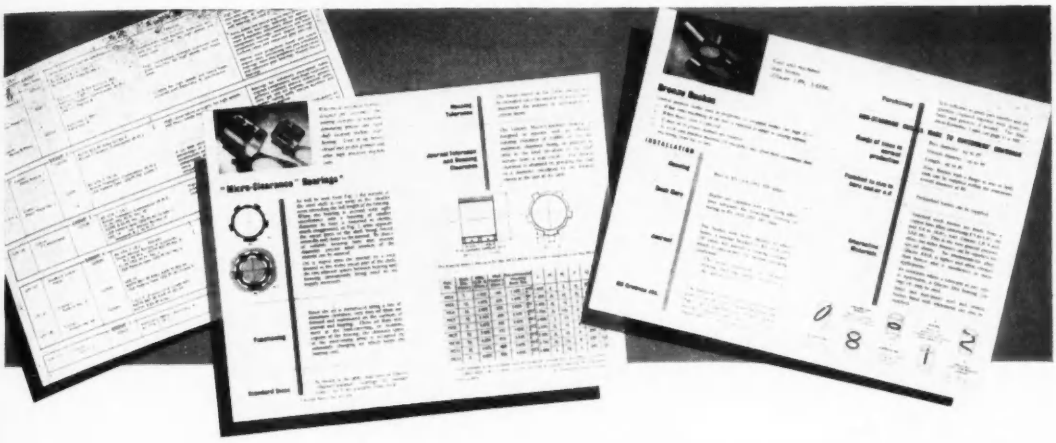

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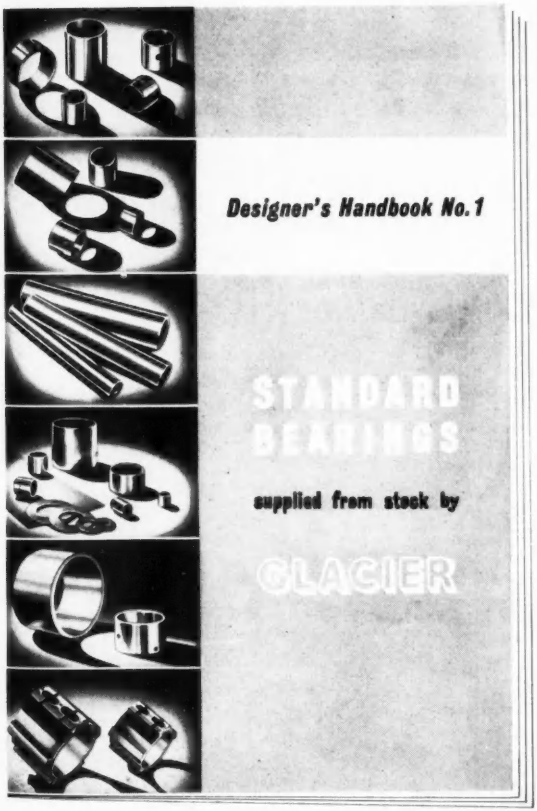


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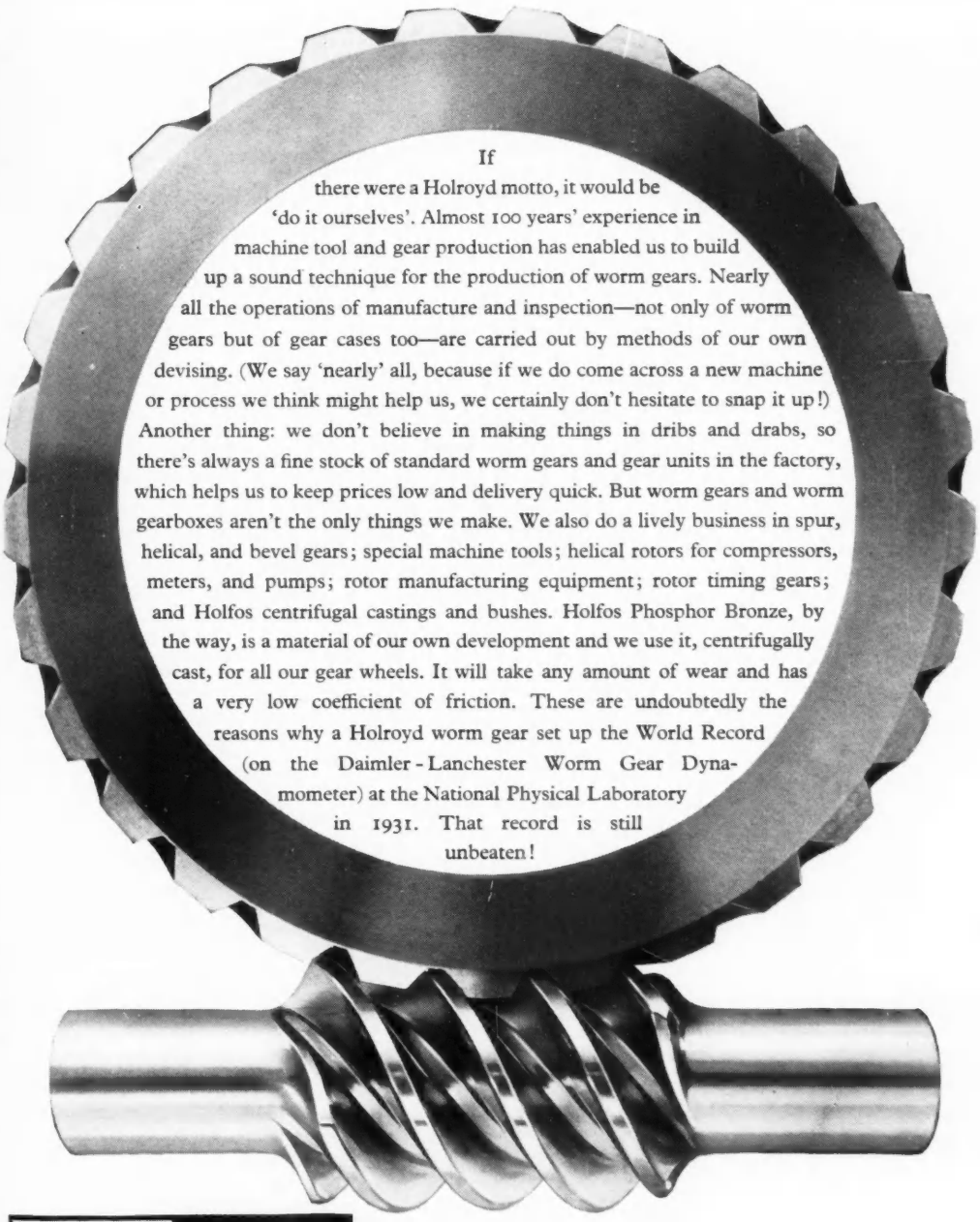

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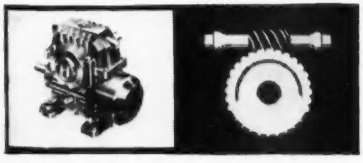

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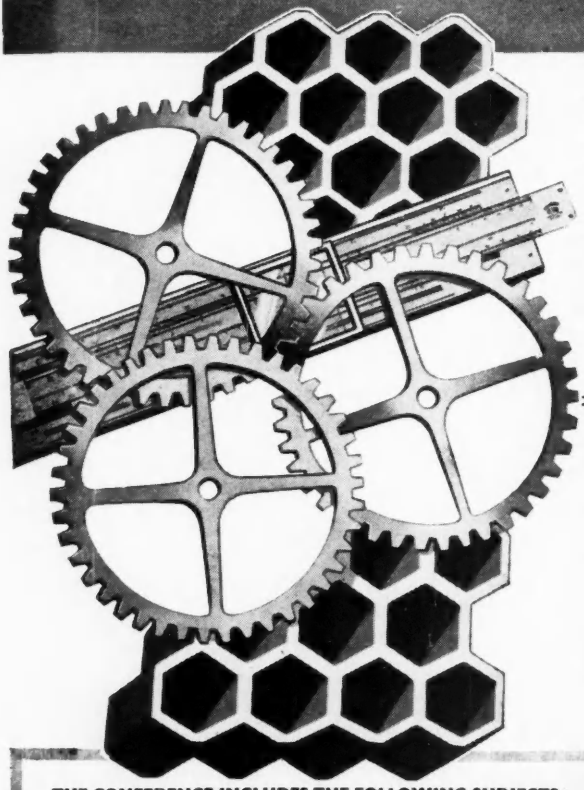

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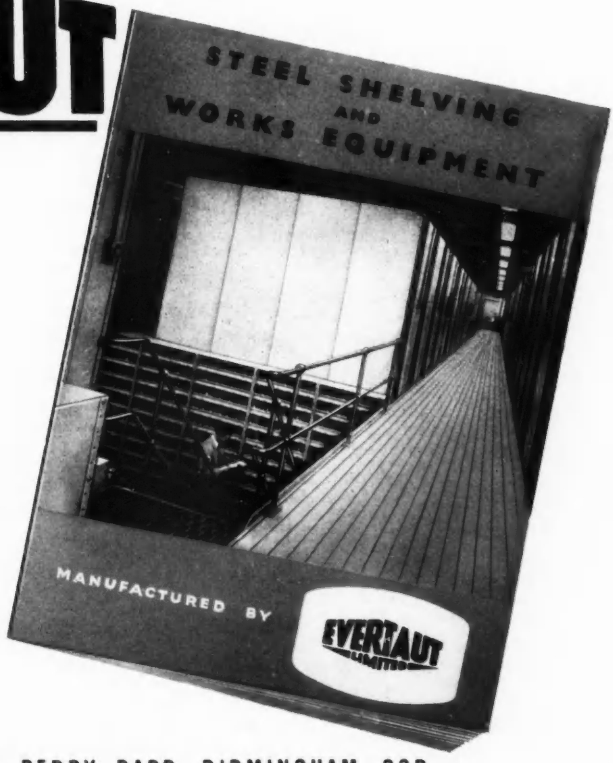


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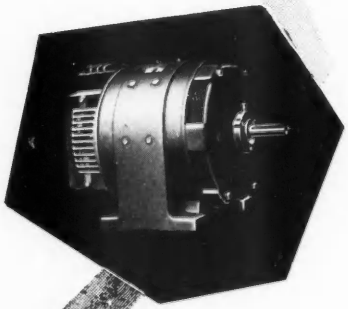

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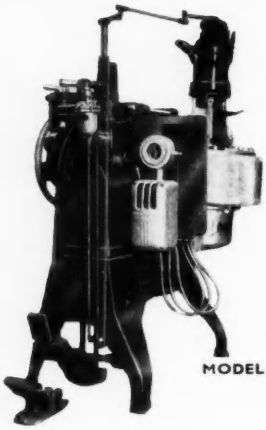

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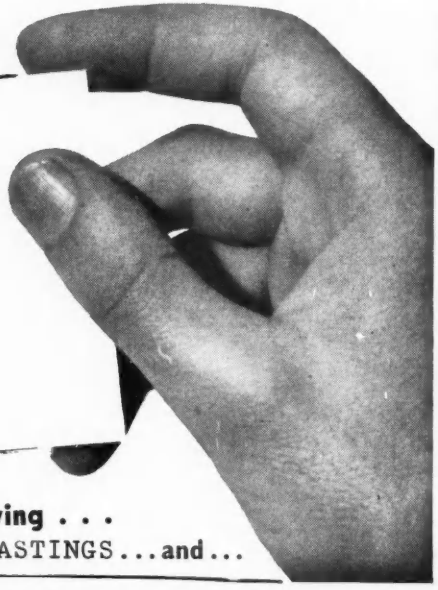

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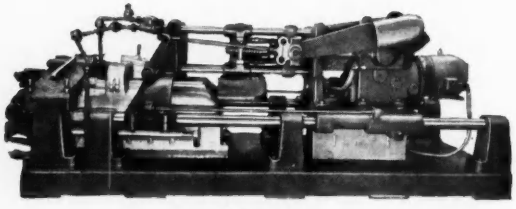
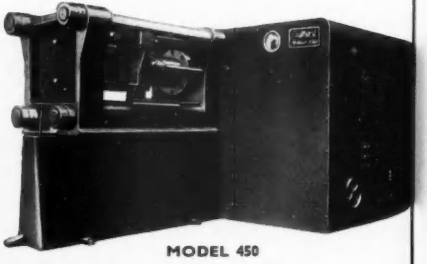


MODEL 4



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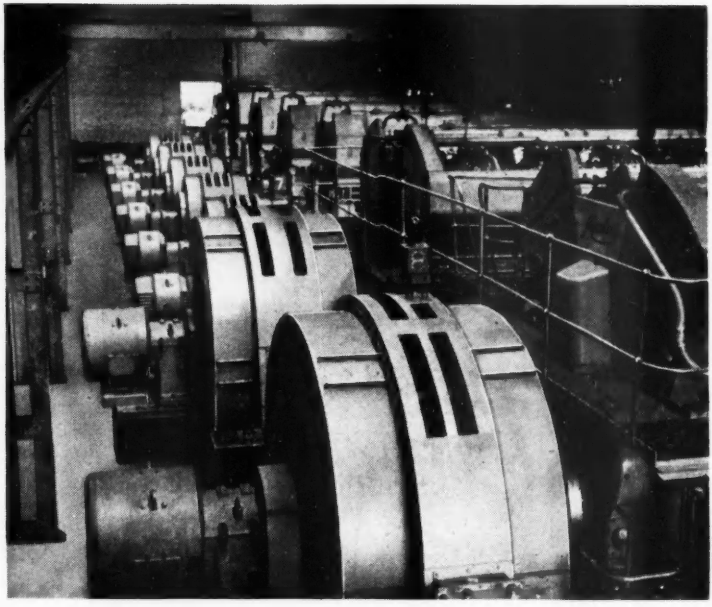

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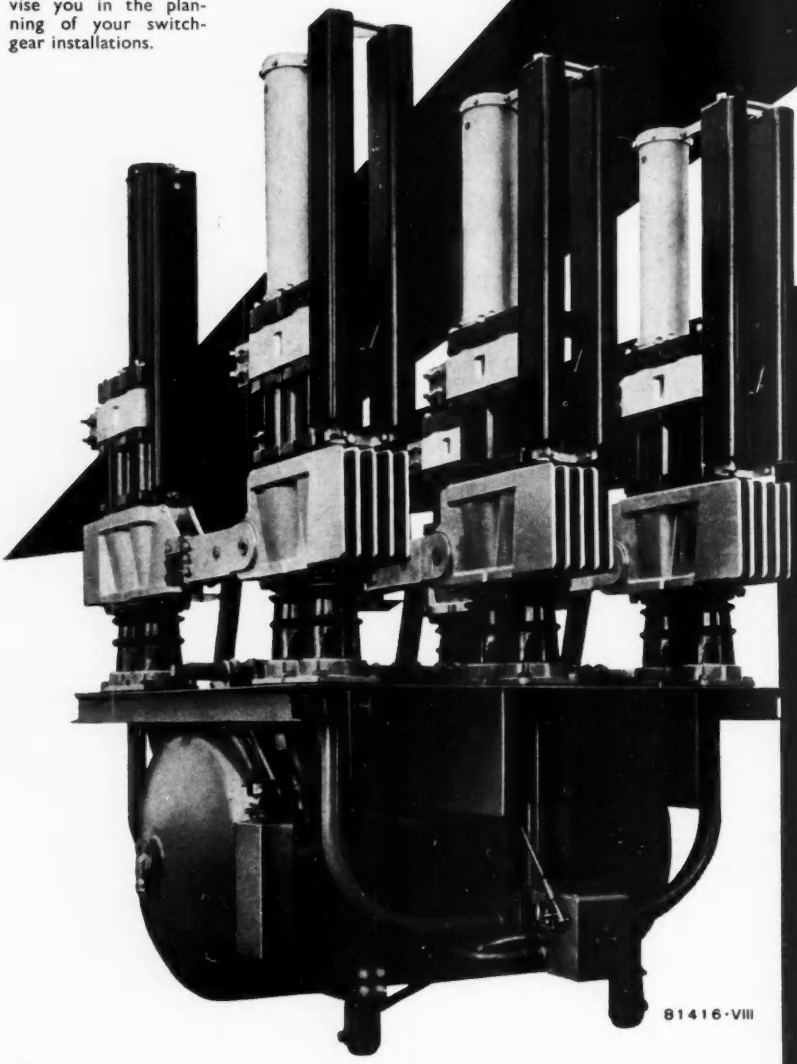


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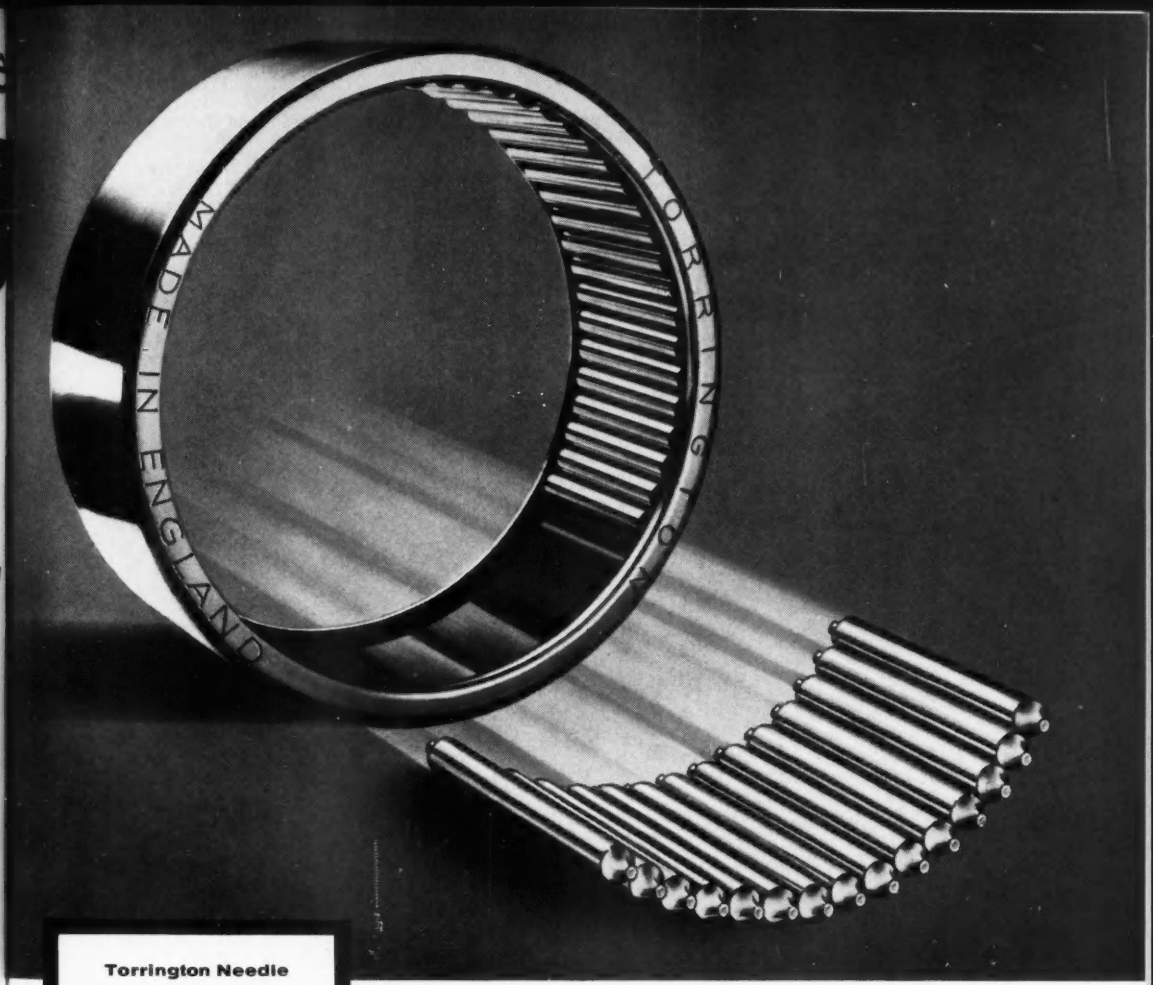


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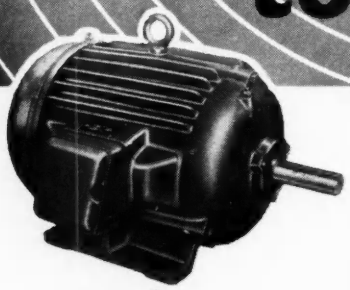

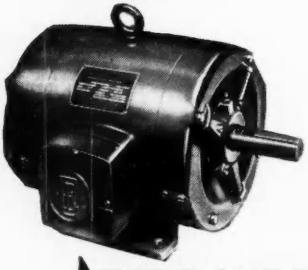

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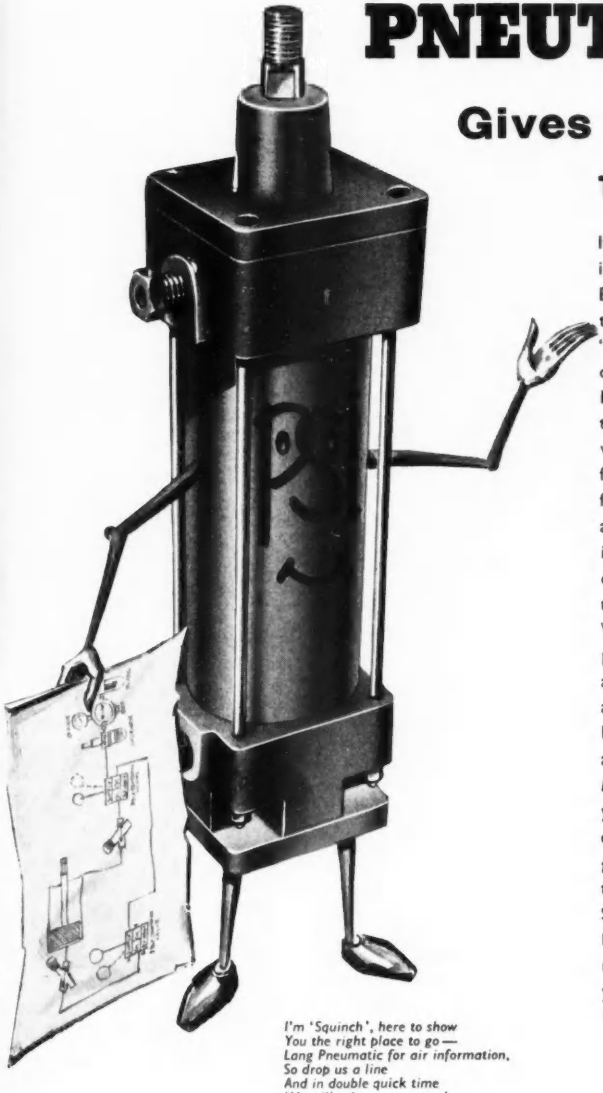

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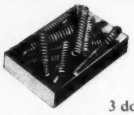

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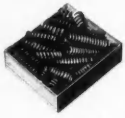

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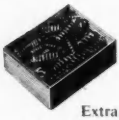

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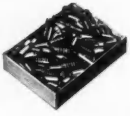

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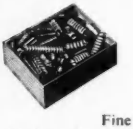

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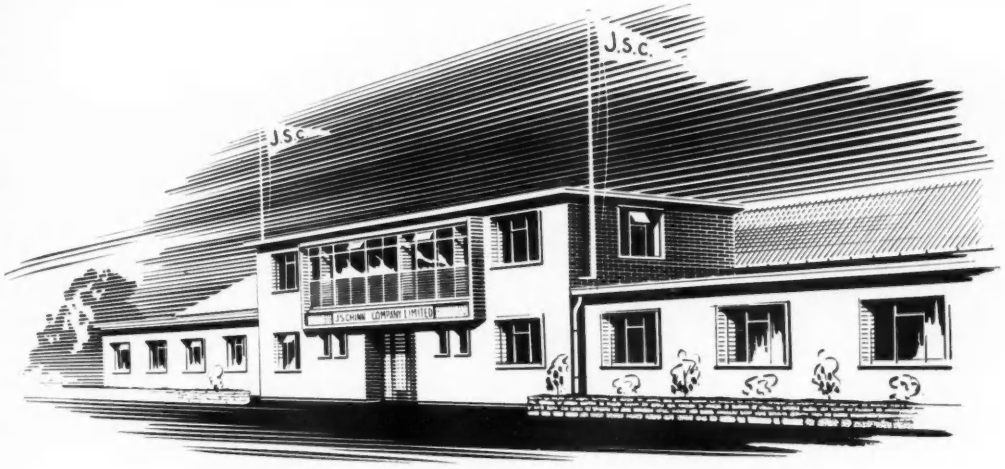


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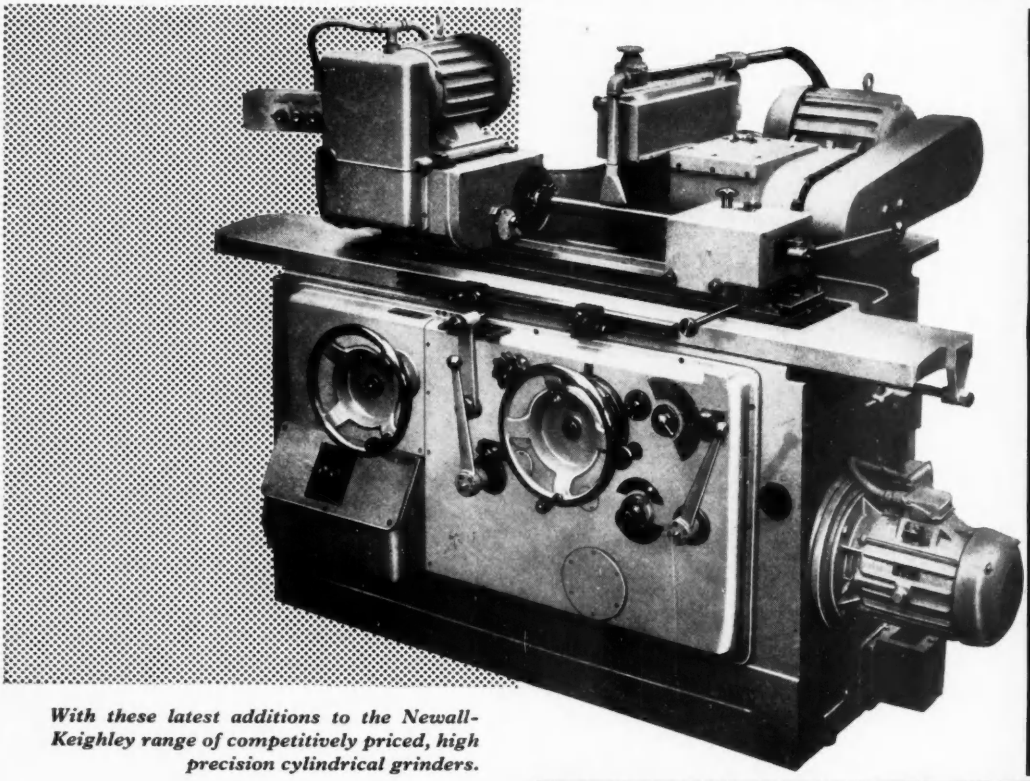

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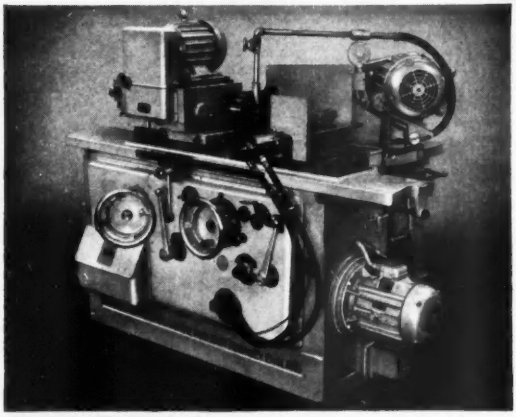

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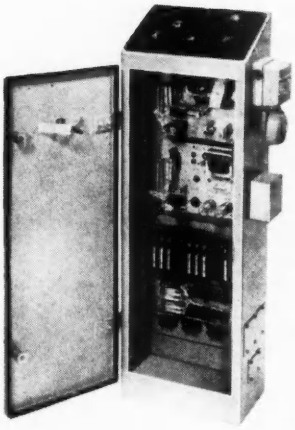

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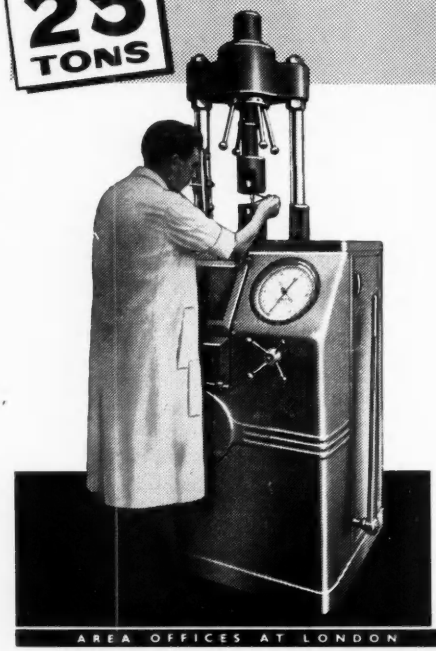

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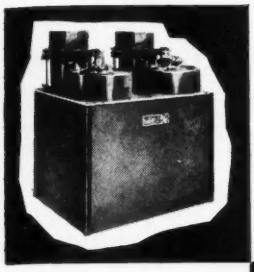
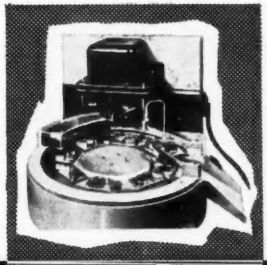
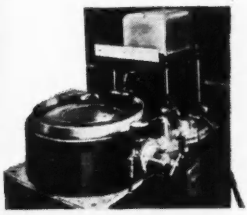
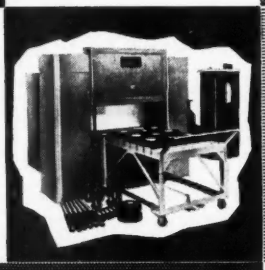


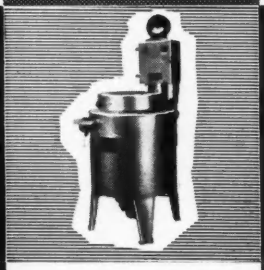
**INDUCTION HEATING EQUIPMENT**

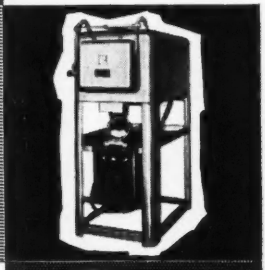


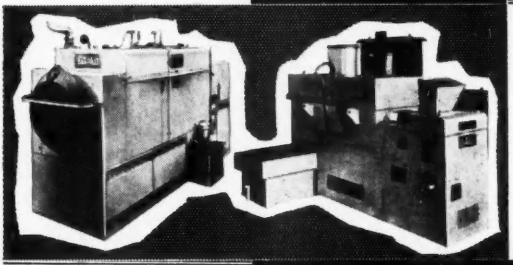


**GENERAL PURPOSE FURNACES**

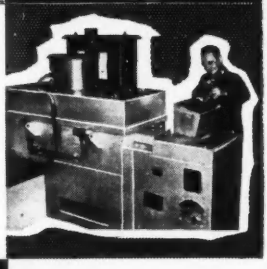


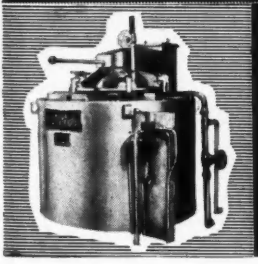


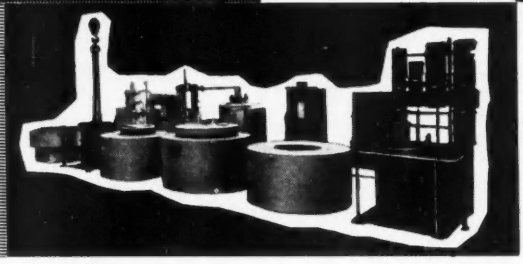




**CONTINUOUS CARBO-NITRIDING FURNACES**







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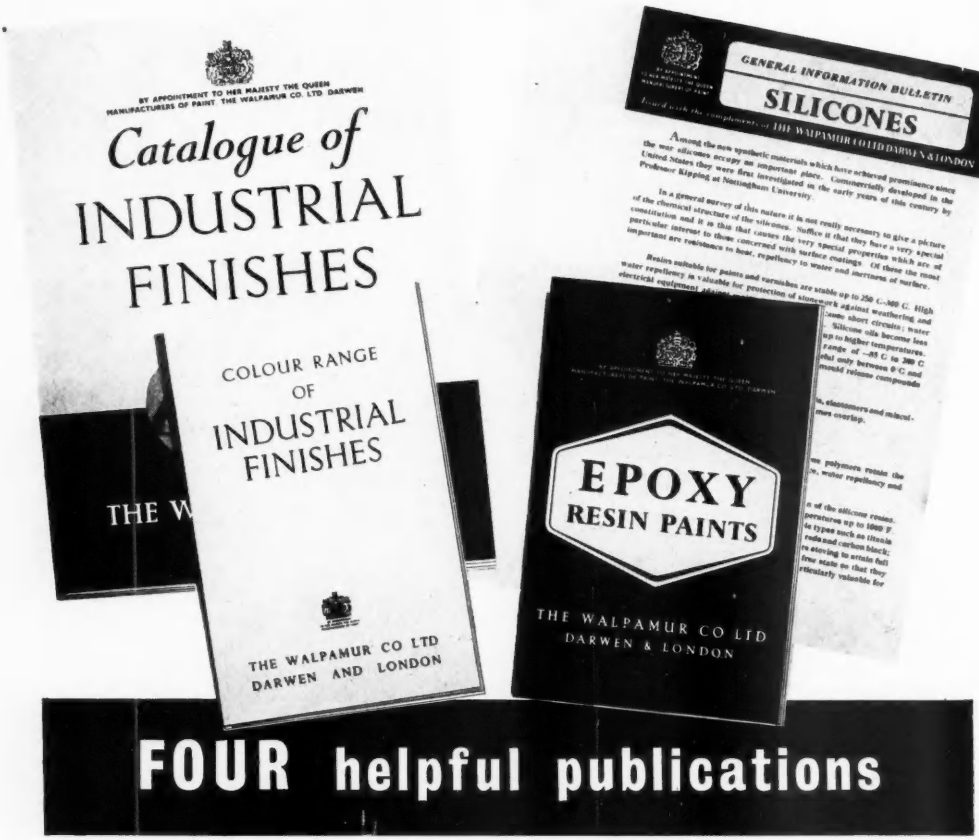


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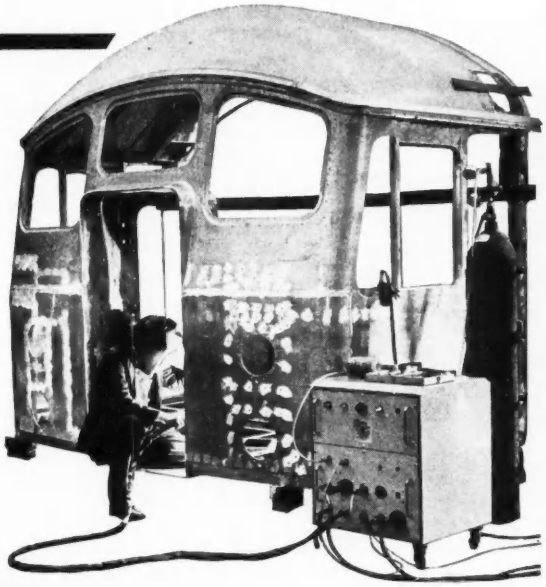

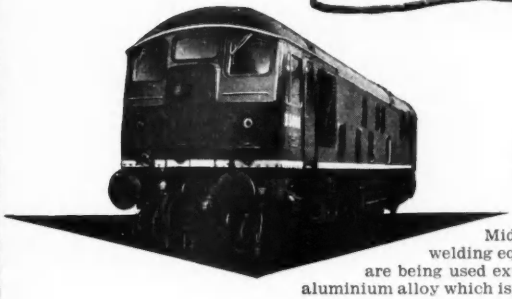

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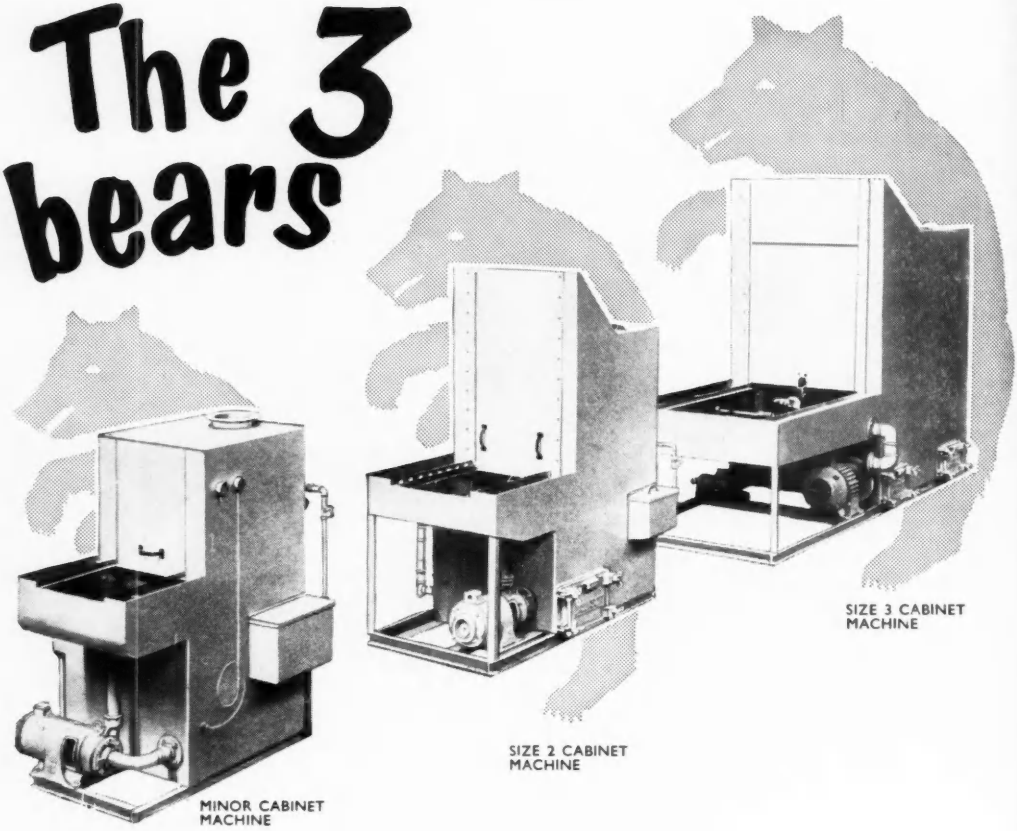

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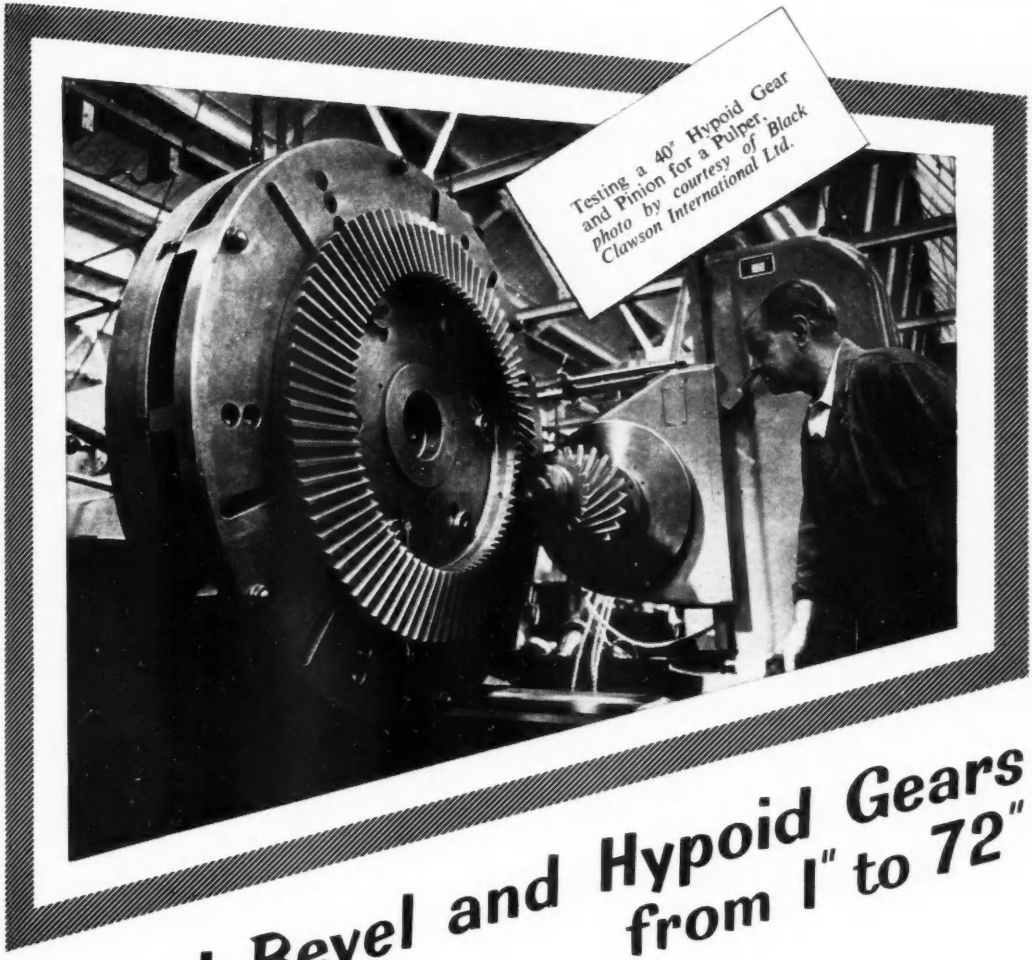


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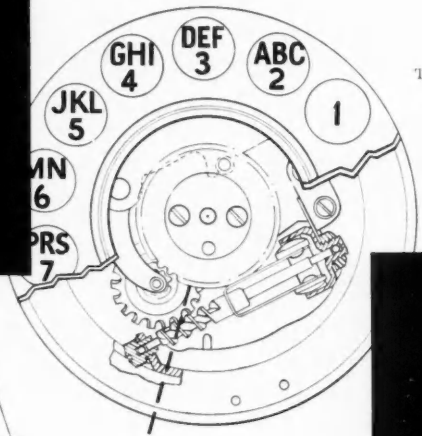


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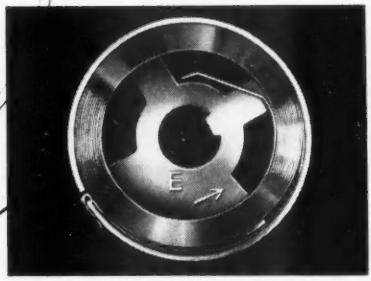

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# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### • *POWDERED ALUMINA AS A POTTING MEDIUM*

A basically new approach to the problem of protecting electronic components involves the use of aluminium oxide powder, which, it is stated, can be used successfully to insulate or pot transformers and other electrical or electronic components in hermetically sealed cans, replacing the more conventional semi-fluid materials hitherto used. In this connection, popular potting compounds include mineral-filled asphalts such as sand asphalt, which has good heat-transfer properties but has a relatively low melting point (135 to 150°C), so that, when it melts, it expands, threatening the hermetic seal and often damaging the component. Alumina powder, on the other hand, does not have these disadvantages, as its melting point is over 1500°C, i.e., well above the operating temperature of any electrical apparatus. Furthermore, it does not expand or contract to any noticeable extent over a wide range of temperature fluctuations, and does not require curing or vulcanizing for use, as is the case with some of the plastic compounds, so that no strains are imposed on the component. It should also be appreciated that alumina is completely inert and is stable at high temperatures, so that it can be used as a single potting compound over the entire range of required temperatures, and imposes no fire hazard, either during potting operations or in use, as distinct from inflammable asphalts or resins.

The preferred physical form of the alumina powder is spherical. In this shape, the granules pack well but do not have the abrasive characteristics of more irregular shapes. The powder, which is readily available at prices which are competitive with those of conventional materials, also has another unique advantage over asphalts, epoxy resins, and similar potting compounds in that it maintains its dry granular form in use, so that components can be removed for inspection or repairs, when required, simply by breaking the seal and pouring out the powder.

From *News from Bell Telephone Laboratories*, New York, December 8, 1959.

### • *FILTERS FOR THE REMOVAL OF TOXIC SUBSTANCES FROM EXHAUST GASES*

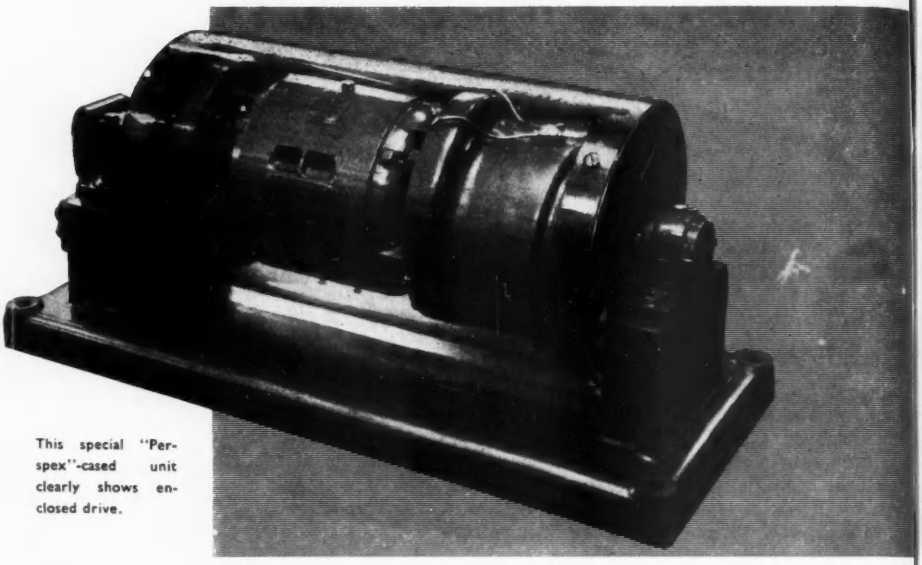
In previous proposals to remove the toxic constituents of exhaust gases of internal combustion engines by filtering, use has been made of activated carbon or silica gel as the filtering medium. While it must be admitted that these materials have a high degree of absorption, they are primarily effective in respect of vaporous exhaust components. Thus, lubricating-oil vapours are readily retained, whereas the particularly harmful tarry combustion residues are insufficiently taken up. To obviate this defect, the proposal has been made to utilize at least one filter unit containing natural or synthetic meerschaum, a compact soft white hydrated magnesium silicate, as the filtering medium. Experiments have shown that this substance has a particularly high absorptive capacity in respect of tarry combustion residues produced in considerable quantities, particularly when the fuel-air mixture is especially rich in fuel.

Meerschaum is also claimed to be very effective as a binder for the combustion products of the plumbiferous anti-knock substances generally added to petrol; furthermore, it is said to be similarly effective for the absorption of exhaust-gas components containing nitrogen and, above all, of ammoniacal components. Additional filters may be provided which contain substances giving off oxygen, these substances being embedded in kieselguhr, their purpose being to render harmless admixtures of carbon monoxide in the exhaust gas. The meerschaum used in the filters is preferably in the form of relative coarse grains or strips which, in addition to their external surface area, provide a large internal surface, owing to the inherent porosity of meerschaum.

From *Brit. Pat. Spec.*, 825,462, Ernst and Andreas Bauer, Vienna, Austria.

### • *THE INFLUENCE OF ULTRASONIC WAVES ON THE CEMENTATION OF STEEL*

A report from Poland relates the results of an investigation into the influence of ultrasonic waves on the cementation of steel, using specimens of low-carbon steel containing 0·12% C. All specimens were cemented in a carburizing medium of 70% charcoal, 20% $BaCO_3$, and 10% $Na_2CO_3$. The temperatures employed were 850, 900, and 1000°C, and for each temperature the length of the carburizing process was 30, 50, and 120 minutes. For comparison, similar specimens were cemented without ultrasonic treatment. The ultrasonic frequency used was about 28 kcs, and the power of the generator was about 35 W. By producing standing waves



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in the specimens, nodes occurred in certain places where tensile stress was zero. It was found that the influence of ultrasonic waves on the carburizing process depends on the magnitude of tensile stresses produced in the specimen. For small intensities, an increase occurs in the carbon diffusion, increasing the depth of the cemented layer. When the intensity is above certain limits, graphitization occurs during cementation, the highest degree of graphitization being observed in places of greatest tensile stress, where the specimens sometimes fractured. All fractures occurred in precisely determined places, in accordance with the state of tension produced by the ultrasonic standing waves. The segregation of graphite produced by ultrasonic waves is caused by the acceleration of carbon diffusion, as well as by the fact that the tensile stresses give rise to graphitization.

From *Archiwum Hutnictwas*, Poland, No. 2, 1958, pp. 125-146.

● ***IMPROVEMENTS IN THE MANUFACTURE OF SILICON STEEL***

It is well known that silicon steel of low carbon content is particularly valuable for electrical purposes because the crystal lattice of the grains can be oriented by appropriate rolling and other treatment. Steels made by conventional processes, such as the acid and basic Bessemer processes, employing atmospheric air as the oxidizing agent, suffer as a class from the presence of such impurities as nitrogen in amounts sufficient to reduce the magnetic properties of the final product. In other respects, however, these processes have important advantages insofar as the manufacture of high-grade electrical steels is concerned, because very low carbon contents can be produced readily and consistently, and contents of objectionable "tramp" elements such as copper, chromium, and tin are characteristically low.

According to a new process, silicon steel capable of orientation and suitable for electrical purposes can be made in stages. In the first stage, a steel base is produced by blowing molten pig-iron in a basic converter, using throughout the blow, or during the later part of it, a blast of a mixture of oxygen and an endothermically dissociating gas or gases, such as oxygen and carbon dioxide, or oxygen and steam. If the mixture of oxygen and endothermically dissociating gas is used only during the later part of the blow, the blast in the earlier part is oxygen-enriched air, which may be preheated, if desired. By producing the steel base in this way, it is possible to reduce the carbon content to less than, say, 0·03%, and the nitrogen content to less than 0·003%, with a minimum of contamination by tramp elements. At the end of the blow, the converter slag is almost completely separated from the surface of the molten steel, so as to ensure that, when the steel is in the ladle, there is no risk of phosphorus re-entering the steel from the slag. This second stage involves the use of two ladles in sequence, the molten metal being poured from the first ladle through a bottom nozzle to prevent the passage into the second ladle of any slag that may have entered the first ladle. In the third stage, silicon is then added to the molten metal in the second ladle.

From *Brit. Pat. Spec.* 823,313, Richard Thomas and Baldwins Ltd., London, England.

● ***OPEN SUBMERSIBLE ELECTRIC MOTORS FOR OPERATION IN SEA-WATER***

It is reported that, during the past few years, efforts have been made towards the development of squirrel-cage induction motors suitable for operation under sea-water. In these motors, a special insulation permits the windings to be submerged indefinitely in sea-water, without any adverse effects on insulating properties. All parts of the motor, such as the shaft and sea-water-lubricated bearings, are constructed of corrosion-resistant materials, with the exception of the electrical steel laminations used for the rotor and stator cores. Operational experience with this type of motor is stated to have included intermittent submergence and prolonged submergence for periods of 300 hours and about 1½ years. In all these tests, no difficulties were encountered in connection with the electrical insulation, but minor difficulties, which are now being corrected, were noted with regard to satisfactory operation of the bearings. It is considered that the major problem facing the development of satisfactory motors of this type is concerned with the corrosion of the electrical steel used in the rotor and stator cores; in fact, a study of available magnetic corrosion-resistant steels for this purpose indicates that none of the materials tested can be considered sufficiently corrosion-resistant and suitable for use in submersible motors for operation in sea-water. Investigations are now being made into the possibility of developing a suitable corrosion-resistant coating for application to these cores.

From *Bureau of Ships Journal*, U.S.A., October 1959, p. 22.

● ***MODE OF FAILURE OF WIRE ROPES***

The authors of a recent paper point out that many wire-rope manufacturers and machine designers are under the impression that the significant stress in a wire rope is the tensile stress, or possibly the stress due to tension and bending if the rope is bent around a sheave or drum. A previous analysis of experimental data has demonstrated that the critical point in a wire rope is actually the point of contact between wires and that the most important

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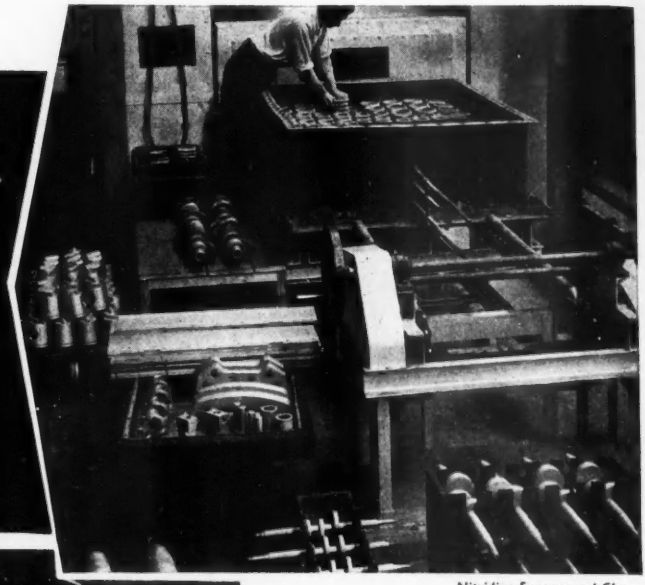

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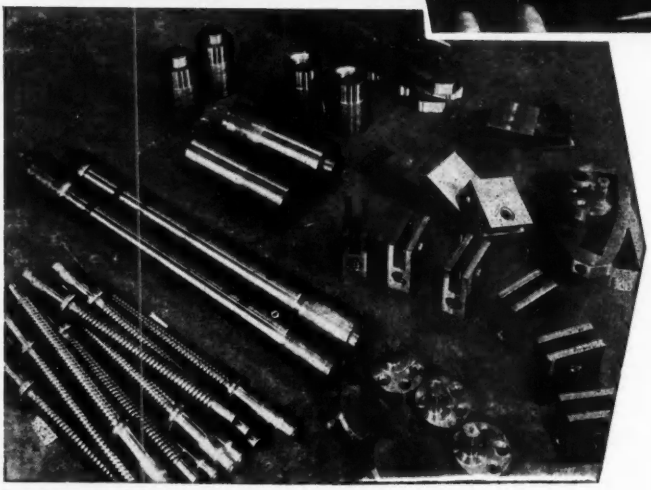

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force-stress relationship associated with this critical point is the Hertzian contact stress induced at this point. The present paper presents theoretical analyses of states of stress at dominant critical points in a wire rope and the results of experimental tests which simulate fretting conditions.

From these investigations it is deduced that the probable mode of failure of a wire rope stems from the fact that high contact stresses, especially at regions where wires cross to give point contact, cause stresses far greater than the yield stress, so that yielding and flattening occur, and subsequent stresses are of yield-stress value. Relative motion of wire on wire takes place, owing to strains in the wires, particularly those due to rope bending, and these relative motions and contact pressures cause fretting, inducing fatigue cracks which first propagate through the highly stressed regions near the points of contact. By the time these cracks propagate out of the highly stressed contact regions, they are large enough to ensure that they will continue to propagate under the less severe tensile and bending stresses prevailing elsewhere throughout the wires.

From *Trans. ASME, Series B*, U.S.A.
November 1959, pp. 307–311.

### ● *FORMATION OF COMBUSTIBLE CHARGE FOR INTERNAL COMBUSTION ENGINES*

In forming the combustible charge of spark-ignited internal combustion engines, the fuel supply system is normally controlled by the flow of induction air through the passage in the induction system. In order to produce a sufficiently large pressure drop when the engine is idling, the cross-sectional area of the passage is restricted, and this restriction has an adverse effect on the volumetric efficiency of the engine when it is operating near to maximum power. In a recently patented arrangement, however, this difficulty is overcome by metering the fuel under pressure to a separate supply pipe for each engine cylinder with a mechanism which is responsive to the pressure drop caused by air flow through one of two parallel passages in the engine air-induction system. A valve located in the second passage so controls the air flow through the second passage that the pressure drop across the first passage does not fall below a certain value. In this way, the first passage can be restricted so as to produce a sufficiently strong pressure drop when the engine is idling, while the combined size of the two parallel passages is sufficient for high volumetric efficiency of the engine.

The position of the valve in the second passage can conveniently be controlled by the engine throttle, by the pressure drop produced by air flow through the first passage, or by the vacuum in the air-induction system. The response of the fuel-metering mechanism to the pressure drop produced by the air flow through the first passage preferably varies with the position of the valve in the second passage, so that the desired fuel-air ratio of the charge is maintained.

From *Brit. Pat. Spec.* 825,322,
General Motors Corporation, Detroit, U.S.A.

### ● *MAGNETO-HYDRODYNAMIC POWER GENERATOR FOR SPACE TRAVEL*

A new approach to the generation of electric power in space travel has been suggested and is based upon the method of magneto-hydrodynamic power generation by extracting electric current from the motion of an ionized gas heated to about 5000°F and passed through an electric field. In principle, this method utilizes the classic electrical phenomenon of producing a voltage in a conductor by passing it through a magnetic field. By using a hot ionized gas, such as high-temperature air and allowing it to stream through the magnetic field, the advantage is obtained that the current can be drawn off by means of stationary electrodes, so that no moving parts are involved—an important advantage from the aspect of operational reliability—the energy contained in the high-temperature air plasma, consisting of ionized atoms and electrons and obtained from, for instance, an arc or a burner, being converted directly into electrical energy.

Magneto-hydrodynamic power generation can be based on an open or a closed cycle. In the closed cycle, the ionized gas is continuously circulated in a closed circuit, using a suitable pump. In space travel, the gas supplied by the pump could be heated by solar radiation prior to entering the generator, after which it would be cooled by radiation, so that it enters the suction side of the pump in a cool condition. In the open cycle, the hot gas could be discharged from a small solid-propellant rocket motor into the generator. Electric power generation in this case would, of course, be of only short duration, e.g., 1 to 3 sec. The possibility of using thermofusion devices for the same purpose also exists.

From *Electronics*, U.S.A.,
November 27, 1959, pp, 82, 84, 85.

### ● *COPPER-COATED STAINLESS-STEEL WIRE FOR COLD-HEADING*

It is claimed that fasteners made from copper-coated stainless-steel wire have superior strength and grain structure. The copper coating, which is applied in an electrolytic plating machine, serves as a lubricant when producing bolts, nuts, and screws by cold-heading. The electrolytic plating machine is so designed that it plates the wire as it passes through the machine in a continuous strand in the form of a spiral. For this

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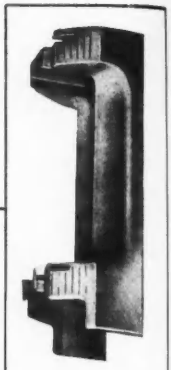

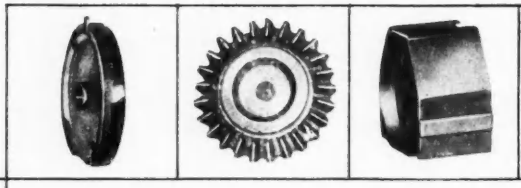

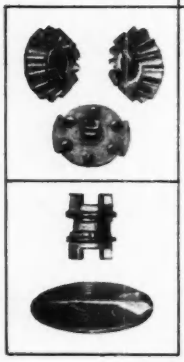

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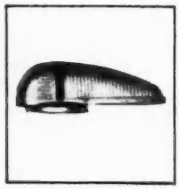

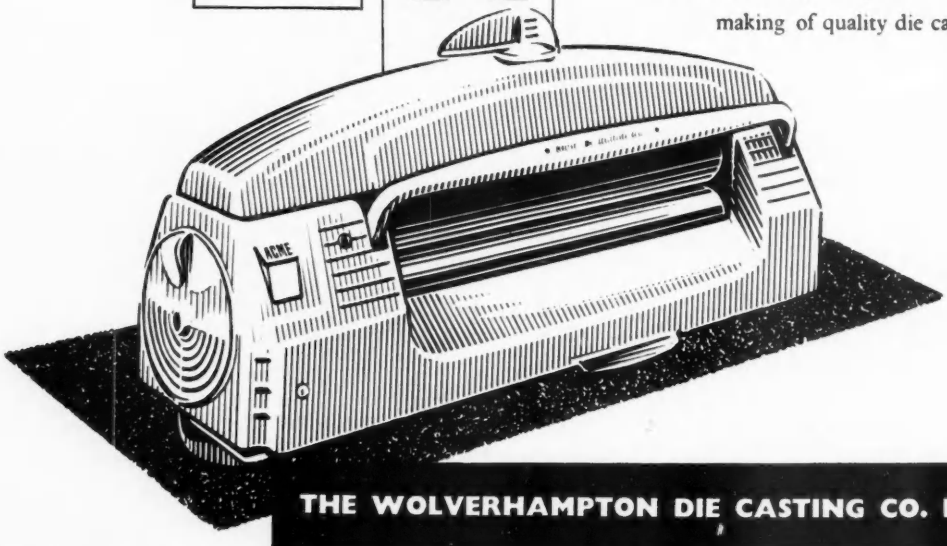


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purpose, the wire, prior to entering the plating machine, is preformed into a helical coil of 36 in. diameter. The copper coating applied to the wire is 0·0002 in. thick and is removed from the finished product by dipping in nitric acid.

This electrolytic coating process is claimed to be superior to the former process in which the coils are oxide-coated and then drawn through a stearate compound, this process resulting in non-uniform coating thickness, bare spots, and flaking. In the new process, hot-rolled rods are annealed, pickled, and drawn almost to the finished wire diameter, after which the wire is annealed and pickled. In the plating machine, the coils pass through a degreasing bath and a cold-water rinse, preventing carry-over of the degreasing solution to the other plating-tank compartments. The wire then passes through a cleaning bath of sulphuric acid, a second water rinse, and a hydrochloric acid tank. After a final water rinse, the wire next enters a plating bath, in which a flash of nickel is deposited on the stainless-steel surface, followed by a water rinse and a caustic bath to neutralize any acid remaining on the nickel. It then passes into the copper-plating solution, after which it receives a final cold-water and hot-water rinse.

From *Steel*, U.S.A.,
November 16, 1959, p. 116.

### ● *PRODUCTION OF CERAMIC AND METALLIC BARS OF UNLIMITED LENGTH*

The usefulness of a new process, capable of compacting metallic or ceramic powders into bars and strips of large cross-section and unlimited length, becomes obvious when it is considered that many new alloys and metal-ceramic mixes needed to-day can only be produced with powder-metallurgy techniques. Previous methods are limited, because of small strip thicknesses, small batch quantities, and expensive equipment, whereas the new continuous process is said to be as versatile as it is simple. Thus, loose powder is placed in a trough and is then pressed with a punch, and, by a succession of pressing operations, a continuous bar or strip is produced.

Many cross-sectional shapes and sizes can be produced with the process, but only 1- and 2-in. channels have been produced so far, though there is no reason why wider bars cannot be pressed, the required capacity of the press, other conditions being equal, increasing with the strip width. The amount of advance per stroke can vary over a wide range; however, if it is too short, the operation will be inefficient and, if it is too long, a smooth bar cannot be obtained. Consistent density can be achieved over the length of the bar, and an outstanding feature is the excellent quality of the surfaces, edges, and corners. Bars have been made from various commercial types of iron powder, including electrolytic iron and Swedish sponge iron. In addition to pure metal powders, a variety of alloys has been pressed from elemental powder mixes, including iron-nickel magnetic alloys, iron-silicon alloys, and many others. Titanium sponge, sponge-iron melting stock, columbium roundels, and tungsten and molybdenum powders have been made into electrodes for further melting.

From *Westinghouse Engineer*, U.S.A.,
November 1959, pp. 172–173.

### ● *CONTROLLING THE CROSS-SECTIONAL CONTOUR OF WELDING ARCS*

A recently patented process aims at improving arc-welding techniques, especially inert-gas-shielded arc welding, by controlling the cross-sectional contour of the arc. At the same time, some of the features of the process could also be applied to the control of cross-sectional contours of electric arcs for purposes other than welding. As is well known, in conventional electric-arc welding the cross-section of the arc is generally circular, while its outer contour is conical, owing to the fact that the arc plasma diverges from the arc towards the workpiece, whereas, in the new process, the arc contour is changed to suit the requirements of the particular welding problem. When, for example, a linear weld is to be made, it is more efficient to make the arc fan-shaped, in order to confine the heat of the arc more closely to the region where the weld is to be made, and it is claimed that this has the effect of making the welding process more efficient with respect to loss of heat from the arc. Also, the penetration of the weld heat into the marginal parts of the piece to be welded is minimized.

The change in arc contour is effected by creating a magnetic field transversely to the arc by means of at least four magnetic poles of alternately opposite polarities, these poles being spaced symmetrically around the arc. The field produced by the poles reacts with the magnetic field created by the arc current and spreads the arc into a fan shape. By using six poles, the spread is along three radial planes, and the cross-section of the arc is Y-shaped. If eight poles are used, the arc is spread along four radial planes, and the arc assumes an X-shaped section.

From *Brit. Pat. Spec.* 823,504,
Air Reduction Co., Inc., New York, U.S.A.

***Readers desiring further information on any developments reported in THE BLUE PAGES are invited to write to the Editor. Copies of the full specifications of any British patents mentioned should be obtained from the Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C.2. Price 3s. 6d. each.***

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VOL. XXI. No. 1 JANUARY, 1960

# Science or Engineering?

By D. R. CORSON

From *The Cornell Engineer*, U.S.A.,
Vol. 25, No. 2, November 1959,
pp. 26–28, 1 illustration

STUDENTS with an aptitude for mathematics and technical subjects in general often decide to study engineering, only to discover that they are more interested in pure science and must therefore redirect their academic programme. Sometimes, of course, the reverse holds true, and the redirection is from science to engineering. However, in both cases, it may be said that the original selection of the field and the subsequent change are often made without a clear understanding of the differences between science and engineering.

Basically, the distinction between science and engineering is simple. Science is concerned with the discovery of knowledge, and engineering is concerned with the application of already discovered knowledge. The scientist is interested only in understanding some aspect of the world in which he lives, while the engineer is interested in the design of some well-defined end-product which has a useful application. For example, the formulation of the laws of mechanical motion by Newton in the seventeenth century was science, while the application of these laws to the design of a rocket motor is engineering. More recently, while the discovery of uranium fission in 1939 by Hahn and Strasman was clearly science, the design of a nuclear reactor core to-day is engineering.

Sometimes the distinction is not so clear, as in the case of the studies by Shockley, Bardeen, and Brattain concerning the motion of electrons and holes in semiconductors and the consequent development of the transistor in the late 1940's. Was this science or was it engineering? Was the transistor "discovered" in the course of a scientific study or was it "invented" as part of an engineering development? The studies of semiconductors which led to the transistor were scientific studies. The transistor came directly from these studies and was developed by the same people, so that it can be claimed as a scientific discovery. On the other hand, its significance lies in its application to engineering problems, so that it can equally well be called an engineering development. What we call it is a matter of taste.

The distinctions between science and engineering become hazy where (1) the period between discovery and application is short, as in the case of the transistor, (2) the engineer needs scientific information in a field that has not been fully explored, or (3) the solution of an engineering problem requires the engineer to dip deeply into the store of existing scientific or mathematical knowledge. These three categories are somewhat arbitrarily defined and the last two stem to a considerable degree from the first.

A good example of category (1), where there is a short period between discovery and application, is the maser, in which very weak, high-frequency radio signals can be amplified through the interaction of the radio waves with the magnetic moments of atomic systems in suitable materials. The solid-state maser was first proposed in 1956, and almost immediately low-noise amplifiers based on it were under construction. Subsequently, a whole series of other maser-type devices has been invented and built by men who were trained as physicists in some cases, and as engineers in others. They have all been concerned, however, with both science and engineering. Without understanding the physics of the device they would be lost, and without an interest in building a device to be used for engineering purposes, they would not be concerned with masers in the first place. They are scientists and engineers at the same time.

Fluid dynamics in high-velocity air flow is an example of category (2), where a field is not adequately explored. The fluid mechanics applicable to air flow over wings at high velocity had not been fully developed when designs of supersonic aircraft were initiated. This was an area of scientific investigation which had not attracted the wide range of study required for engineering applications. As a result, aeronautical engineers attacked the problem on both the theoretical and the experimental side, with the result that the thermodynamics and aerodynamics involved were worked out. These studies were applied to the engineering problems concerned, the swept-wing and delta-wing were developed, shock-wave troubles were cleared up, and supersonic aircraft were produced.

Another example in category (2) is the case of an engineer who wishes to design a nuclear reactor to operate at such high temperatures and in such corrosive atmospheres that no existing metal is suitable as a structural material. If the science of materials were far enough advanced, the engineer could utilize established principles to design an alloy for his purpose. Since the basic science is not available, the engineer must experiment himself with new metals and new alloys to try to find one which is suitable. In the process, he may make studies to understand why a small amount of one metal alloyed with another has such profound effects on the properties of the second metal. In this effort, the engineer's work is hardly distinguishable from that of a physicist studying

metals. The engineer, however, always has the design of his reactor in mind.

An example of category (3), where the direct application of existing knowledge requires extensive scientific analysis, is the case of an aeronautical engineer trying to understand shock waves. He finds that the thermodynamics of the gas in the shock front is not at all what he predicted from his fluid-dynamics theory, which he had extrapolated from the behaviour of gases at lower temperatures, pressures, and velocities. The explanation of the discrepancy lies in the fact that the temperatures in the shock waves are high enough to excite molecular vibration or rotation states that are unfamiliar to the engineer. These vibrations and rotations absorb energy from the shock wave and completely change the specific heat of the gas, thereby changing the thermodynamics of the system. Without an insight into the atomic and molecular properties of the gas, the engineer would be lost.

In each of the examples cited above, the engineer uses techniques or makes investigations which are essentially scientific in nature. In a narrow view of the engineer's work in these cases it is not possible to distinguish the engineer from the scientist. In a broader view, however, it can be seen that, as already mentioned, the work of the engineer is always directed towards some useful application. The pure scientist, on the other hand, is seeking knowledge for its own sake.

The engineer who studies the properties of unusual metals may go rather deeply into the subject before he finds the alloy which solves his problem, but once he has solved his problem, he goes ahead with his engineering design. The physicist who studies the same problems is, however, only trying to understand the atomic phenomena involved. If he solves one problem, he goes on to another with the hope of developing a complete understanding of all the basic atomic processes involved.

Sometimes, however, the line between science and engineering cannot be drawn at all, as in the case of an electrical engineer who works in the field of radio astronomy. If he is not a competent radio engineer, he cannot design the apparatus he requires for his studies; if he is not a competent astronomer, his work is apt to be trivial. He must be both engineer and scientist to work in such a field. Whether he calls himself an engineer or a scientist depends on his original field of study and on who pays his salary.

There is another factor which characterizes the engineer, especially in the more traditional engineering fields, and this is his responsibility to the public. If a structural engineer designs a bridge, the bridge must be completely safe under all possible conditions. At the same time, the design must be economical to build and pleasing from an aesthetic point of view. The engineer must be sure that he has exercised good " engineering judgment " in his design, and that his product will perform the job to be done, will be producible, will be reliable, and will be easy to service. However, the physicist studying mesons, for example, has no similar responsibility, being concerned only with learning as much as possible about the subatomic world.

(*Concluded on page 96*)

# *Causes of Rotor Failures*

# in Three-Phase Squirrel-Cage Motors

By R. Braun

From *Der Maschinenschaden*, Germany,
Vol. 32, No. 9/10, 1959,
pp. 138–143, 18 illustrations

In three-phase squirrel-cage motors, various designs of cage are used, but failures can occur in all designs and can be due to various causes. In the manufacture of the cage, the bars are brazed to end rings, the entire ring assembly, complete with bars, first being preheated and the melting temperature of the brazing alloy then being reached by local application of further heat. As the bars are not subjected to this latter heating process simultaneously, but consecutively, there can be no doubt that the completed assembly will contain residual stresses. At each position where brazing has been carried out, there are two adjacent bars, one stressed in tension and the other in compression. The general stress level will be particularly high if there is a marked difference between the preheating temperature and the melting temperature of the brazing alloy. Bars under tension will be more likely to develop cracks, whereas there is less danger in the case of bars under compression.

In some double-cage designs, the bars of the starting cage and the bars of the running cage are brazed to the same rings. As the two sets of bars are exposed to different thermal conditions, they will be subjected to different stresses. Fractures mainly occur in the starting cage, as the bars in this cage have a smaller cross-section than that of the bars in the running cage. During the starting process, only the bars in the starting cage expand, and the distance between the rings is kept fairly constant by the bars in the running cage, so that the starting-cage bars are subjected to end loads and buckling. On the other hand, when running at normal speed, the running-cage bars expand, whereas the starting-cage bars, owing to good cooling conditions, do not, so that failures in the starting-cage bars can easily occur as a result of the tensile stresses induced.

Uneven stresses due to differential expansion can also occur in correctly designed cages because, owing to the absence of bar insulation, creep currents can give rise to local hot-spots. Consequently, the individual bars in the cage can become unequally heated and therefore expand unequally.

Furthermore, the cooling conditions of the individual bars may vary because they are not identically embedded in the cage slots. The axial freedom of the bars must also be considered as, even with round sections, jamming can hinder axial elongation of individual bars. Additional

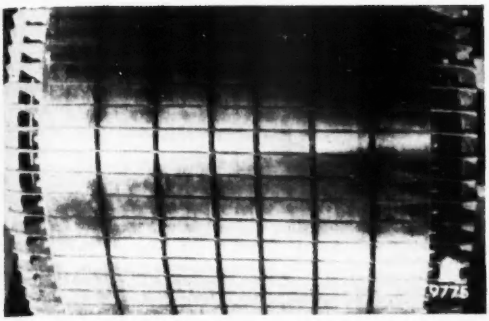


Fig. 1. Rotor of a 500-kW mill motor with bars of trapezoidal shape, showing gaps between the laminations and the end rings.

Fig. 2. Portion of a rectangular bar, showing cracks in the brazed surface caused by embrittlement.

constraints can occur through local welding of laminations to the copper bars, constraints of this type being more pronounced if the bars have a narrow trapezoidal shape. In addition, centrifugal force can drive bars of this shape into the slots and correspondingly reduce their axial mobility. During the starting process, a similar effect is produced by electrodynamic forces, particularly if the slots are cut more deeply than necessary as regards bar dimensions, in order to facilitate the insertion of the bars into the laminations in fairly long machines. Buckling phenomena can also occur when thick rectangular or tapered bars are clamped by means of wedge-pieces at the ends of the slots. Buckling of the middle portion of the bars causes additional tensile stresses and is also a possible source of vibration, leading to bar failures.

The bar ends of rotor cages are particularly subject to vibrations when there is a gap between laminations and the end rings (Fig. 1), as acceleration or deceleration, e.g., during starting or under suddenly applied loads, causes elastic deflections of the bars. These deflections can become appreciable with heavy end rings and comparatively weak bars, and the resulting vibration can cause fatigue fractures of the bar ends, particularly if the copper becomes embrittled owing to the heat generated during operation (Fig. 2). In a number of designs, the brazed portions of the bars are made of a smaller cross-section than the middle portions. In such cases, the bar ends are the weaker sections and, even with careful brazing, cracks are easily formed at the brazed joint ends (Fig. 3).

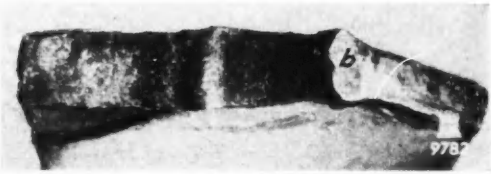



Fig. 3. Bar from the rotor of a 1250-kW three-phase motor used for driving a boiler feed-pump. The bar ruptured at the brazing position, failure being due to thermal loading. The fracture initiated at position *b*.

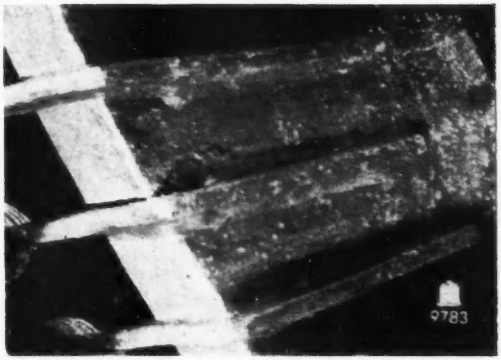



Fig. 4. Crack in an end ring from a 450-kW, 750-rpm motor.

In addition to these stresses due to design features, frequent starting under comparatively heavy loads can be regarded as one of the major causes of bar failure. Similarly, the end rings can fail from centrifugal forces, eccentric positioning, and torsional vibration, as well as from material or brazing defects (Fig. 4). End-ring construction can also be weakened by screwed-on balance weights, which can cause ring fractures (Fig. 5).

Fig. 5. Crack in the end ring of a blower motor. The crack can be seen across the screwed hole used for fitting a balance weight.

Fig. 6. End ring from a 125-kW blower motor, showing damaged bars near the brazing positions and a crack at position *r*.

Cracks in bar sections within the slots are generally vibration fractures, or brittle fractures at brazed positions where two bars have been joined together to obtain the required bar length. Cracks outside the slots occur particularly as a result of high thermal loads and non-uniform cooling conditions for the individual bars. Such cracks are also observed in synchronous motors provided with starting and damping windings. Cracks in brazed joints mainly appear when extensive changes in the crystalline structure of the copper have occurred during the brazing process, these changes tending to weaken the bar at this position, and these fractures are accelerated by torsional vibration of the rings.

If many bars have fractured in a rotor cage, it is frequently noticeable that the centres of gravity of these fractures are equally spaced around the ring periphery, with an interval equal to the pole pitch (Fig. 6). The explanation of this regular pattern is that, after fracture of the first bar, not only those bars adjacent to it, but also those situated at multiples of the pole pitch are electrically overheated, thus creating thermal conditions which are conducive to further bar fractures.

In the case of end rings of welded construction, fractures usually appear at weld positions and are caused by excessive stresses due to speed or load (Fig. 7). These fractures generally exhibit the characteristic features of a brittle fracture.

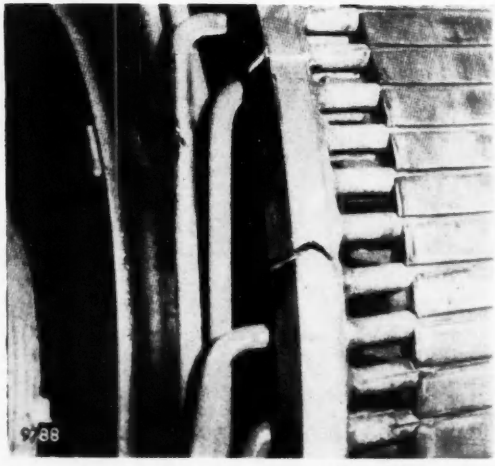



Fig. 7. Fracture in the starting cage of a 125-kW, 750-rpm motor, owing to overload.

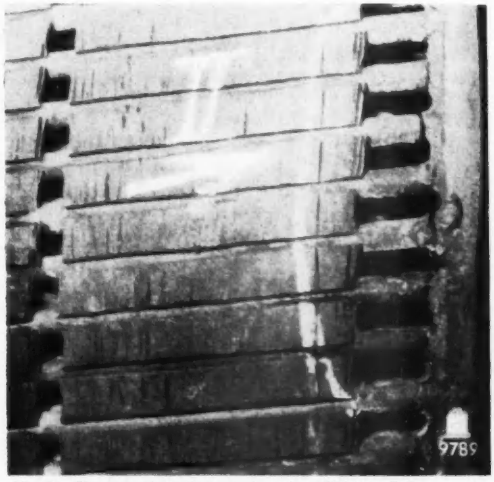



Fig. 8. Fracture of starting-cage bars in a 125-kW, 750-rpm motor used in a coal-crushing plant, as a result of overloading.

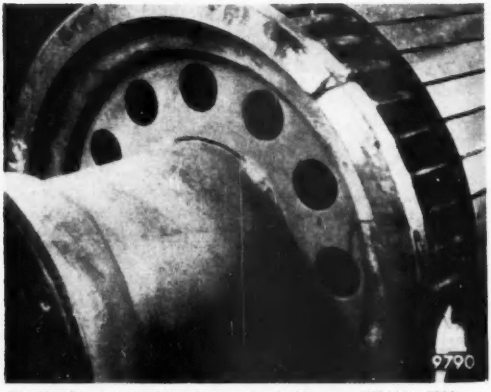



Fig. 9. Fracture in the end ring of a double-cage 185-kW, 1500-rpm blower motor.

Certain types of drive seem particularly prone to rotor-cage fractures, particularly those with high torque requirements, considerable variations in load, and severe starting conditions, e.g., in coal-crushing plant (Fig. 8), blower drives for boilers (Fig. 9), especially when the effects of blower inertia are not sufficiently taken into account, and lift drives, which are subjected to frequent starting and stopping operations and changes in the direction of rotation.

# *Photographic Analysis of Arc-Furnace Operations*

By J. A. Brosovic

From *Iron and Steel Engineer*,, U.S.A.,
Vol. 36, No. 11, November 1959,
pp. 85–93, 10 illustrations

Arc-furnace operations in the steel industry have experienced an intensive growth period during the last few years. Furnace capacities are nearing the 200-ton mark, while transformer capacities of 36,000 kVA and graphite electrodes as large as 24 in. in diameter have already become common-place, and furnace practices have broadened to include the production of almost all grades of steel.

Simultaneously with this growth, furnace operating and maintenance problems have become more serious and costly, but fortunately the scope of technical services and facilities capable of coping with these problems has also grown. Instrumentation, previously restricted to the laboratory, has been made mobile for quick transportation to production locations, thus providing a means by which the conditions surrounding the problem can be accurately and extensively surveyed. For example, photographic equipment, previously too fragile for steel-mill use, has been made more rugged and can now move in to record the conditions surrounding the problem from close-up vantage points too hazardous for human observers. Also, data-processing systems, previously restricted to accounting work, have been adapted to eliminate the time-consuming task of calculating, tabulating, and plotting the pattern of conditions surrounding a problem.

This paper covers the co-ordinated approach used by production, maintenance, and laboratory personnel to isolate the cause of a serious refractory maintenance problem and to devise a preventive maintenance technique capable of reducing its ill effects to a tolerable level.

The specific problem examined was the occurrence of refractory-lining "hot spots" in areas of the lining located above the slag line, as shown in Fig. 1. At these points, refractory materials of all types experience an extremely short life span. Almost continuous patching between heats is required, and unscheduled shut-downs often occur during the course of a lining campaign for the purpose of replacing brickwork destroyed in these hot spot areas. The exact location and severity of the hot spots vary with individual furnaces and furnace practices, thus adding to the difficulty encountered by masonry departments in prescribing suitable refractories for hot-spot service. It is sufficient to say that, at the start of this investigation, the hot-spot problem had become so serious as to justify the cost of installing expensive super-refractories and water-cooling pipes in an attempt to extend refractory life in the affected areas.

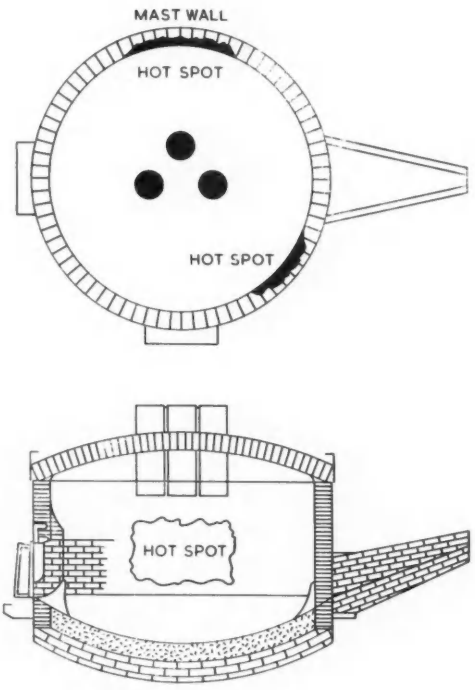



**Fig. 1. Typical locations of hot spots in an arc furnace.**

The first stage of the operational plan of this investigation was centred on exploring the environmental conditions surrounding a hot-spot area. The key factors believed to be most capable of causing accelerated refractory damage in these areas were as follows:—

(1) Exposure of the hot-spot area to high impact loads such as might occur during top-charge scrap drops.
(2) Exposure of the hot-spot area to sustained and concentrated attack by gas, dust, volatile matter, small high-velocity molten particles, or radiant heat energy.

The actual mechanics of refractory destruction proceeds by way of many complex chemical, thermal, and mechanical processes. Each of these processes is too complex for discussion in this paper, but the effectiveness with which each process can accelerate refractory destruction is determined by the interrelationship of the key factors just mentioned.

The first of these factors, high impact loads, can in most cases be ignored as a direct cause of hot spots. Performance reports assembled by the furnace crews and maintenance personnel revealed the existence of hot spots of equal severity on side-charge furnaces, which do not experience scrap drops. Similar, but less severe, hot spots have also existed in furnaces using a high percentage of hot metal charge and also those involved in duplexing operations. It is possible, however, to inflict severe damage to any portion of a lining if it is struck by a scrap drop. Therefore, in certain cases, hot-spot area destruction may proceed more swiftly because of this type of supplementary mechanical destruction of the refractory materials.

The other factors suspected of causing hot-spot

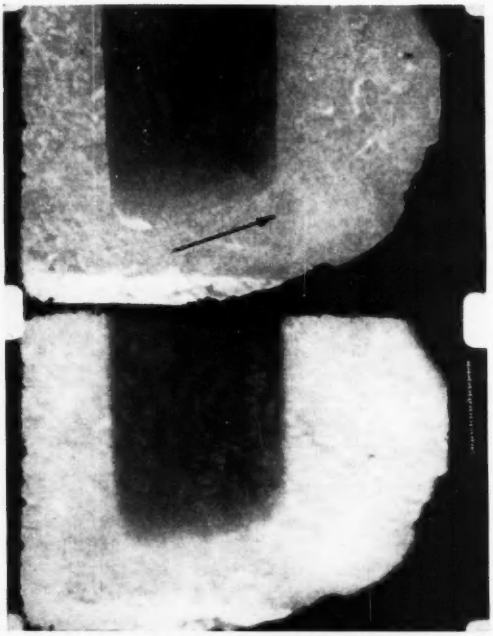


Fig. 2. Effect of electrode-tip configuration in directing destructive energy towards the hot-spot area.

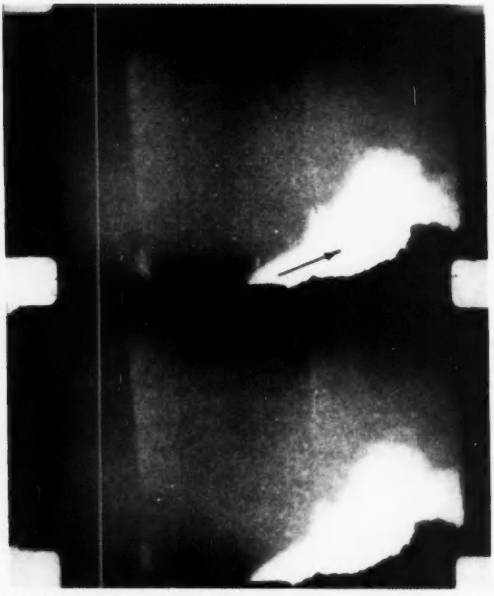


Fig. 3. Part of a motion-picture sequence of gas, dust, and volatile matter travelling towards the hot spot.

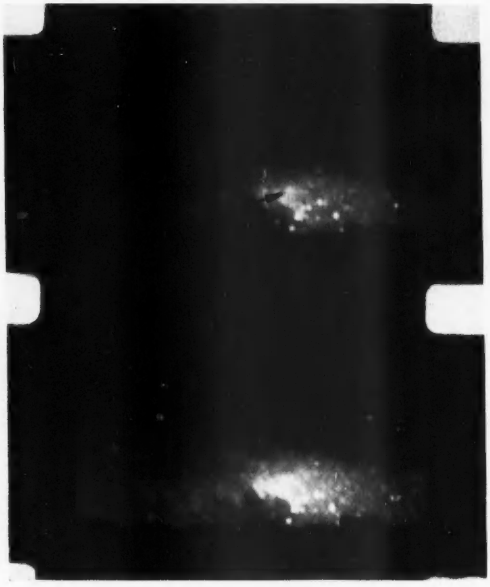


Fig. 4. Part of a motion-picture sequence showing molten particles travelling towards the hot spot.

damage are concentrated attacks on the refractory lining by gas, dust, volatile matter, small high-velocity molten particles, and radiant heat energy. Visual observation of both the interior and exterior of the furnace during the course of any heat will quickly verify the existence of each of these conditions. Normal and high-speed photographic analysis of the hot-spot areas within the furnace, however, revealed a concentration of each condition existing in the hot-spot areas. In each case, the arc zone, i.e., the area where electrical energy is converted into heat energy, appears both to create the condition and also to supply the motivating force necessary to propel it into a hot-spot area. The electrode-tip configuration forms the chamber within which these forces are generated by the arc and the orifice which directs them towards the hot-spot area.

Oxidation, vaporization, dissociation, and reduction of the various materials in the arc zone are the predominant sources of gas, dust, and volatile matter. Physical forces generated by these reactions, along with strong magnetic fields surrounding the arc, are believed to supply sufficient force to disturb the bath and slag surfaces, and generate frequent sprays of molten particles. Rapid changes in the distance between the electrode tip and bath surface regularly develop long exposed arcs capable of supplying large amounts of radiant energy. In each case, however, the electrode-tip configuration appears to be the controlling factor in directing this destructive energy towards the hot-spot area. For example, in the case of gas, dust, and volatile-vapour attack, comparisons were made of the relationship between the hot-spot location, the electrode-tip configuration, and the stream flow towards the hot-spot area. Thus, Fig. 2 shows the electrode-tip configuration, the arrow indicating the direction of the hot spot, while Fig. 3, which is part of a motion-picture sequence of the brilliant flow towards the hot-spot area, shows gas, dust, and volatile matter travelling in the direction of the arrow towards the hot spot. It should be noted that the attack stream originates in the arc zone and is directed into the hot-spot area by the electrode-tip configuration. A similar com-

parison that can be made for small high-velocity molten particles is illustrated in Fig. 4, which is part of a motion-picture sequence showing these molten particles travelling towards the hot spot in the direction of the arrow.

The radiant-energy attacks occurred in the same manner, but at a more rapid rate. In many cases, the radiant-energy stream appeared to flash the sidewall at the same frequency as the arc-voltage supply (60 cps) and appeared most intense during the positive half cycle. Fig. 5 is part of a motion-picture sequence showing energy radiated in the direction of the arrow towards the hot spot.

Thus far it has been illustrated how the experience of the furnace crews and maintenance personnel was combined with normal and high-speed photography to determine the physical conditions capable of causing refractory damage in hot-spot areas. The common origin of each condition was defined as the arc zone, while the electrode-tip configuration supplied the means of focusing each condition into a hot-spot area.

A puzzling feature of these studies, revealed by supplementary photographic investigations of the interior of the furnace, was that, even though similar conditions existed at all three arcs, corresponding hot spots did not necessarily occur. The relatively short duration of each film made it impossible to determine whether the overall intensity or frequency of occurrence of each condition was the same in each area. The accelerated rate of refractory destruction in the hot-spot area, on the other hand, established that either the intensity or frequency of attack, or a combination of both, was of greater magnitude in the arcs adjacent to a hot spot.

At this point in the investigation, the two basic problems requiring solution were (1) to determine what phenomena caused certain arcs to generate hot spots, and (2) to devise an economical method of controlling these destructive phenomena.

The extreme scarcity of pertinent factual and fundamental data on the electrical and physical behaviour of high-current melting arcs, together with the impracticability of running a controlled experimental test on a production furnace, made it impossible to make further explorations of arc phenomena; it was therefore proposed to attempt to minimize hot-spot effects by dispersing the destructive conditions over a wider lining area, first consideration being given to changing the electrode-tip configuration in such a manner as to cause wide dispersion of the destructive forces.

Many approaches were suggested towards achieving this goal, and each was examined for its economical aspects and the permanence with which its effects could be retained. The two approaches chosen for field testing were (1) modified transformer loading in terms of voltage and current adjustment, as well as modification of the melting practice determining the extent and sequence of use of each particular voltage tap, and (2) inert-gas injection through hollow electrodes.

Using the instrumentation normally supplied on an arc furnace, no noticeable changes in either the intensity or location of the hot spot were observed over the range of voltage and current adjustments necessary to retain furnace productivity. In certain cases where voltages were reduced and current values were increased to the ultimate safe load limit of the transformer, the electrode tip immediately assumed the flat configuration necessary for wide dispersing of the destructive forces of the arc. Unfortunately, these current values were too high for safe use with the existing secondary bus cables and electrodes.

Modification of the furnace melting practice within the limits necessary to maintain the desired production rate has no significant effect on the severity or location of the hot spots.

Inert-gas injection through hollow electrodes was next explored as a corrective medium. Information derived from the use of this technique in inert-gas welding applications and from previous laboratory and field tests by one electrode supplier indicated that some of the desired benefits of electrode-tip configuration control might be achieved with inert-gas injection with only slightly lesser benefits being gained solely from the use of hollow electrodes.

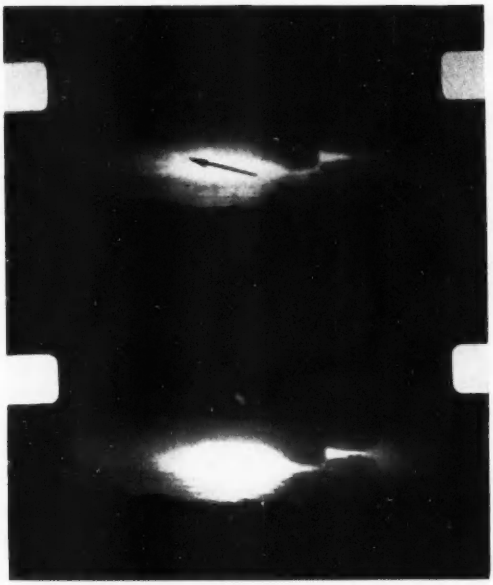


**Fig. 5. Part of a motion-picture sequence showing a radiant-energy flash directed towards the hot spot.**

A decision was made to production-test hollow electrodes, because the use involved no changes to the furnace structure or operating practice. Inert-gas injection tests were delayed pending the completion of the hollow-electrode test. A short test run of seventy-two 20-in. graphite electrodes of varying bore diameter was conducted on a 20,000-kVA, 70-ton, top-charge furnace. As a result of this test, a 1-in. bore diameter centred on the vertical operating axis was chosen as the desired specification for a full-scale test of hollow electrodes.

Prior to the start of the test, the alignment and location of the individual electrodes were checked and found to be proper. Also, the transformer loading on the two highest voltage taps was adjusted to the most efficient levels possible within the rated capacity of the transformer and retained there via automatic control with the tap-changer switch. These checks ensured that each of the arcs was operating in its proper location and at the recommended optimum power level.

The actual testing of hollow electrodes started in conjunction with the installation of a new furnace lining. The test site was a 20,000 kVA top-charge furnace with a rated capacity of 70 tons. The furnace products were common grades of steel using a single slag practice. After

45 heats had been produced with the use of hollow electrodes, the lining exhibited the same hot spots as had been previously observed on this furnace, and extensive patching was required. After patching was completed, the test was resumed, but all data so far accumulated were subjected to a detailed analysis.

A noticeable characteristic of the data analysed was the fact that the electric arc operating adjacent to each hot-spot location exhibited a much higher average power level than the arc located in an area where no hot spot existed. Fig. 6 illustrates the relationship between arc-power levels and hot-spot locations on an intermediate voltage tap.

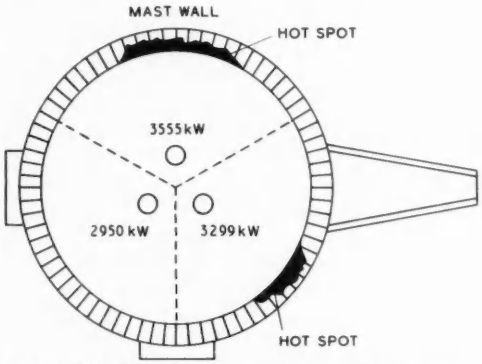



**Fig. 6. Relationship between arc power levels and hot-spot locations, when using hollow electrodes.**

Visual observations of the interior of the furnace during melt-down of the cold scrap charges revealed that the scrap melted more rapidly in the hot-spot areas, thus exposing the refractory lining in these areas to the full destructive power of the forces previously described during the time that the scrap in the other areas of the furnace was being melted. These data provided conclusive evidence pointing directly at the electric arcs as the fundamental cause of refractory-lining hot spots.

Immediate steps were taken to correct the difference in arc power level by adjustment of the electrode regulator control circuits. Considerable manipulation of both the voltage- and current-sensing circuits was required to achieve even an approximate balanced condition. A lack of fine-adjustment provisions in the control components was the main obstacle encountered in making these adjustments and is suspected to be the basic cause of improper control operation.

The test observations continued after completion of the electrode regulator adjustments, and at the end of three complete lining campaigns the results reported from the combined use of hollow electrodes and balanced arc power levels showed a 12% reduction in the consumption of refractory material used for sidewall-lining replacement and a 9% reduction in the consumption of refractory material used for roof or dome replacement, while hot-spot severity decreased to a point where no shut-downs were required between relines.

Since these results included the use of both hollow electrodes and arc power-level balancing, it was difficult to evaluate the benefits derived from each. To clarify this situation, the laboratory instrumentation used for adjusting this furnace was assembled in a simplified form and installed on another furnace experiencing hot-spot difficulties. Prior to adjustment, the furnace exhibited almost identical arc power-level unbalances in the hot-spot location as appeared in the test furnace. The same adjustment procedures were followed, and the same adjustment difficulties were encountered.

Two lining campaigns have been completed to date, and the results are as follows:—

(1) Hot-spot severity immediately decreased, and no shut-downs were required during each campaign for brick-work patches in hot-spot areas.

(2) Electrode breakage during high-power melt-down periods was reduced to an insignificant level.

These results clearly indicated the effectiveness with which the arc power-level balancing technique can help solve the hot-spot problem.

The application of this technique to other arc furnaces will be relatively simple and inexpensive. In most cases, it involves only the procurement and installation of three accurately calibrated meters for measuring the average arc power levels. The exact balancing procedure may vary from furnace to furnace, depending on the control circuitry of different types of electrode regulators. Likewise, the capability of each individual regulator to retain proper adjustment will determine the frequency with which this maintenance technique must be repeated.

Far more development work is needed to gather the basic knowledge necessary to promote more efficient use of the electric arc. In a broad sense, users of arc furnaces have more or less accepted the electric arc as having certain peculiarities, and have done little to control its behaviour or to ascertain its significance to many other furnace operating problems. For the future, the electric arc can be considered as an inexhaustible source of new methods to melt and refine steel, but only after better ways to control it are found.

## Science or Engineering?

(*Concluded from page 90*)

From the above examples, one important fact in connection with modern technology emerges, i.e., that science and engineering are moving closer together. The pace at which new scientific information enters the technological world is so rapid, that the engineer often must be a competent scientist in his own right to be able to design the engineering product with which he is concerned. In fact, the engineer is using more of the techniques of the scientist and is digging deeper into the store of recently accumulated scientific information. For this reason the training programme of engineers in recent years has moved closer to that of scientists.

In the coming age of manned satellites and space exploration it is inevitable that this trend will continue. In consequence, it makes less difference through which door any given student enters the general field. In the more traditional fields of engineering or of science, however, it is still important at present to make a proper choice of field in the beginning. Thus, it is difficult to go into chemistry with a background in mechanical engineering, and it is equally difficult to go into civil engineering with a background in physics. However, these difficulties probably will decrease in the future, as engineering and science curricula attain greater similarity. At the same time, it is true to say that, regardless of the field in which a student ultimately makes his career, the initial choice of college course has, even now, become less important.

# Experiments in the Field of Parametric Amplification

By B. Bollée and G. de Vries

From *Philips Technical Review*, Holland, Vol. 21, No. 2, 1959/60, pp. 47–51, 9 illustrations

In many laboratories a great deal of work is now being put into developing the theory and practice of parametric amplification. The principle of this method of amplification is by no means new, but has only recently come into prominence as a result of research on the low-noise amplification of very weak signals, such as occur, for example, in radio astronomy and man-made satellite communications. In amplifiers equipped with the more or less traditional thermionic valves, a fundamental limit is set to the reduction of the noise level by the random fluctuations of the electron emission from the hot cathode, and in amplifiers equipped with transistors by the statistical nature of the diffusion and recombination of charge carriers, which in this case determine the amplification. Such effects do not necessarily enter into parametric amplification, which is based on the periodic variation of one parameter of an oscillatory system, e.g., the stiffness in a mechanical system or the capacitance in an electrical circuit, and, in principle, it should be possible to achieve an extremely low noise level.

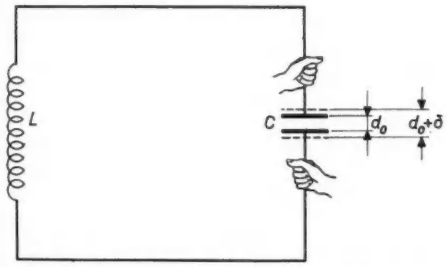


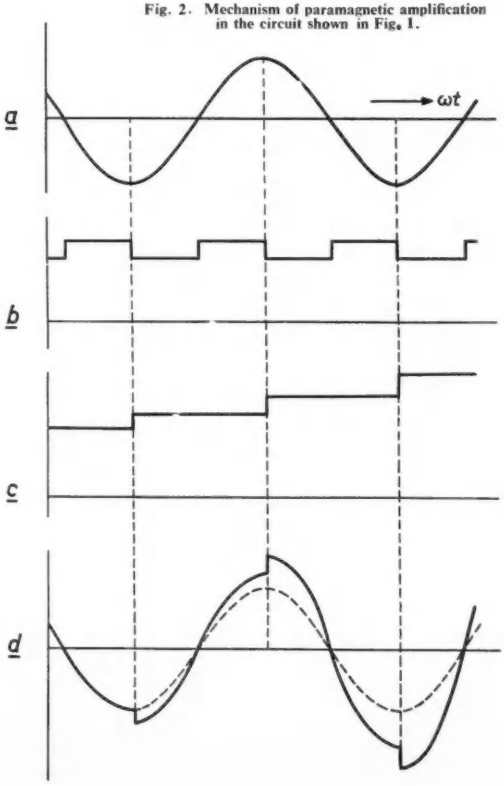

Fig. 1. *LC* resonant circuit with movable capacitor plates.

Although numerous theoretical studies have been published on the mechanism of parametric amplification, and although it has been successfully applied in practice, it cannot be said that its operation is understood and under control to the same extent as the operation of amplifiers fitted with valves and transistors. For example, it is not yet possible to produce an optimum design for a parametric amplifier required to operate with a given frequency characteristic (or bandwidth). The interpretation of experiments in this field is often made more difficult by the absence of exactly defined conditions, so that various effects have to be dealt with that cannot be distinguished from each other.

To explain briefly the principle of parametric amplification, assume a taut, slightly elastic string to be pulled lengthwise at an appropriate frequency; the string will enter spontaneously into transverse vibration with a frequency equal to half that at which it is pulled. An *LC* resonant circuit in which the capacitance is periodically varied may be regarded as the electrical analogue of this phenomenon. If the distance between the plates of a parallel-plate capacitor is $d_0$, and an alternating current flows through the (resistanceless) circuit at the resonant frequency $f = 1/(2\pi\sqrt{LC})$, the charge on the capacitor, and hence the voltage, vary sinusoidally with time. If, at the moment when the charge and thus the voltage of the capacitor reaches a maximum, the two plates are abruptly pulled apart (Fig. 1), this action requires work. If they are subsequently pushed back to their original position at the moment when they are uncharged, no work is produced. Thus, energy is periodically supplied to the circuit and the amplitude of the alternating voltage increases, i.e., " negative damping " occurs.

The process is further explained in Fig. 2. In the initial state, a small alternating current flows in the resistanceless circuit, and the charge and voltage then vary sinusoidally with time, as shown in Fig. 2a. The capacitor plates are now displaced at certain moments, so as to vary the capacitance, as shown by the square waveform in Fig. 2b. This " pumping " causes a stepwise increase of the energy of the circuit (Fig. 2c), and also of the amplitude of the voltage on the capacitor (Fig. 2d). Even though no current flows at the start, a minute disturbance of equilibrium in the form of an extremely small charge, which is always present, is sufficient to initiate the process, and this causes the *LC* circuit to enter spontaneously into electrical oscillation. The frequency at which

Fig. 2. Mechanism of paramagnetic amplification in the circuit shown in Fig. 1.



the capacitance is varied (by moving the plates back and forth), called the pump frequency, is most favourable when it is twice the resonance frequency of the circuit.

The negative damping of a circuit, which may be regarded as an effect arising from a negative resistance, implies the possibility of using it to amplify a given input signal. In this respect, however, the situation is not so simple, if only because of the frequency condition just referred to. For negatively damping an oscillation it is not necessary that the pumping be exactly in phase with the oscillation. The net energy supply from the pump falls, however, as the phase angle $\varphi$ increases. The supply drops to zero at $\varphi = 45°$, and becomes negative at larger phase angles; in other words, the oscillation is then damped instead of amplified, damping being greatest at $\varphi = 90°$. Now, if half the pump frequency (i.e., the resonance frequency $f$ of the circuit) differs slightly from the frequency of the input signal, this is equivalent to a continuous change of phase; the oscillation is thus alternately amplified and (though to a lesser degree) damped, i.e., modulated in amplitude.

In attempts to arrive at a practical means of parametrically amplifying radio signals, where the aim is to achieve useful amplification in a reasonably wide frequency band, the difficulty described has been circumvented by the use of more complicated circuits with two or more resonance frequencies.

Another question concerns the method of carrying out the pumping process. Mechanical variation of an oscillatory-circuit parameter is impracticable because of the excessive acceleration forces involved at the very high frequencies. Variation is therefore effected by means of voltage-dependent capacitances or current-dependent inductances. An example of a voltage-dependent capacitance is the germanium diode, whose capacitance depends on the negative bias. By superimposing an alternating voltage (the pump or control voltage), a periodically varying capacitance is obtained.

Parametric amplifiers have already been built in this way, and are reported to possess favourable properties. These systems, however, are difficult to deal with theoretically, for the capacitance of the diode depends not only on the pump voltage, but also on the oscillatory-circuit voltage to be amplified, a further complication being the non-linear relation between capacitance and voltage. Such systems are called " autoparametric ", as opposed to " heteroparametric " systems of the type shown in Fig. 1, in which the parameter to be varied is influenced only by the pump, and does not react noticeably on the pump. If a current-dependent inductance is used, e.g., a coil or resonant cavity having an iron or ferrite core which is alternately saturated by a pump current (essentially a " magnetic amplifier " long used for low frequencies), this, too, is an autoparametric system, since the circuit current itself likewise contributes to saturation. Thus, although practice points in the direction of autoparametric systems, it is nevertheless desirable for the purposes of fundamental research to concentrate in the first place on heteroparametric systems, such as the mechanically variable capacitor, which lend themselves more readily to theoretical treatment.

The experimental arrangement devised by the authors is of a similar kind, but capacitance variation is effected by a magnetostrictive resonator. The pump consists of a window-frame core (Fig. 3) made of a suitable type of ferrite. This core is centrally clamped and is brought into longitudinal vibration by means of a winding connected to an ultrasonic generator of a frequency of 22 kcs. A

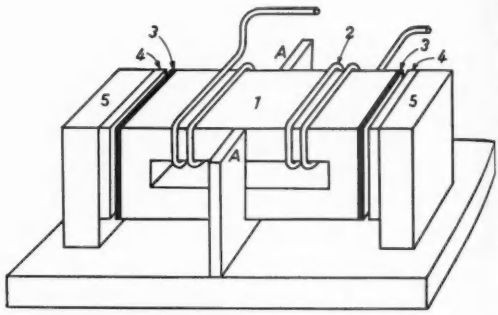



**Fig. 3. Details of construction of a magnetostrictive pump.**
(1) Frame core of piezo-magnetic ferrite clamped at *A*.
(2) Core winding.
(3) Metal plates attached to core.
(4) Fixed plates, spaced 80 $\mu$ from plates (3).
(5) Insulating material.

metal plate of 30 × 80 mm is attached to each of the two parallel-ground end faces. Opposite each plate, at a spacing $d_0 = 80\ \mu$, a parallel, fixed electrode is mounted. The two moving plates are electrically interconnected and constitute one plate of a capacitor, whilst the fixed electrodes, also interconnected, constitute the other plate, the total capacitance amounting to 532 pF. To obtain an oscillatory circuit having a resonance frequency $\omega/2\pi$ of 11 kcs, i.e., half the pump frequency, an inductance $L$ of 0·395 henry is needed.

One of the advantages of this arrangement is that it is easy to produce a purely sinusoidal variation of the reciprocal capacitance, so that an exact theoretical treatment is possible. In particular, it can be demonstrated that the parametric excitation of the natural frequency of the circuit calls for a certain minimum amplitude $\delta$ of the capacitor plates, and that the smaller is this minimum amplitude, the higher is the $Q$-value of the resonant circuit ($Q = \omega L/R$, $R$ being the series resistance of the coil). It can be shown that, provided $\delta/d_0$ is sufficiently small, the condition $\delta Q/d_0 > 2$ must be fulfilled. With the ultrasonic oscillator described above, the breaking strength of the core limits the amplitude $\delta$ to 1 micron. The coil in the resonant circuit must accordingly be so constructed that the value of $Q$ is at least 160.

The amplitude reached by the voltage on the capacitor when the oscillation increases due to the pumping depends, in theory, solely on the pump power. The power supplied to the circuit is $P = \frac{1}{2}\omega C_0 V^2/Q$. At $C_0 = 532$ pF and $Q = 200$, a voltage as high as 3300 V is reached at a power of only 1 W, which constitutes a scarcely noticeable load on the magnetostrictive resonator. A voltage as high as this would obviously cause the capacitor in Fig. 2, with its air gap of 80 $\mu$, to break down. Tests with an air-core coil in this arrangement showed that it was necessary to limit the voltage in order to protect the capacitor, this being achieved by shunting a neon tube across the circuit. This precaution is not, however, required when a coil with a ferrite core is used, as in this case the capacitor voltage does not rise above 250 V, owing to saturation of the ferrite.

An arrangement similar to that described has also been made, using a piezo-electric resonator as the pump. The resonator consists of a quartz-crystal plate about 1 mm thick and with a surface area of about 20 × 20 mm², excited into the thickness compressional mode, the pump frequency being 3 Mcs. With this arrangement, results were similar to those with the magentostrictive pump.

# Thermo-Electron Engines as Practical Power Sources

By G. N. Hatsopoulos, J. Welsh, and E. Langberg

From *Electronics*, U.S.A.,
Vol. 32, No. 46, November 13, 1959,
pp. 69–72, 4 illustrations

During the past decade, considerable research has been devoted to techniques for directly converting heat into electricity without the use of moving mechanical parts. It now appears that practical devices of this type will be available in the next few years for a variety of applications, ranging from space vehicles to household appliances.

Both thermo-electric and thermionic conversion devices have been studied. The thermo-electric technique utilizes the Seebeck effect, commonly known as the thermocouple effect, and prototype generators have recently been developed by various firms, one of the most interesting being a 3-W unit with a reported efficiency of 6½%.

The thermionic technique makes use of the flow of current from the surface of hot bodies when enclosed in a vacuum and, although this effect has been thoroughly studied, only recently has it been seriously proposed for the conversion of heat into electricity. Now, however, thermionic conversion has been the subject of considerable research and development and, despite the fact that early prototypes are likely to produce relatively small amounts of electrical power, i.e., between 0·1 W and 5 kW, the ultimate power levels attainable are no more limited than those attained by large steam-power generating stations. Nuclear reactor technology of the future may also benefit from these developments, as reactors using thermionic conversion will not require circulating fluids and heat exchangers associated with turbines, and thus should be more efficient, compact, and economical.

The basic feature of the thermionic converter is that it partially converts the kinetic energy of emitted electrons into useful electrical energy which can be dissipated in an external load. Thermo-electron engines are technologically similar to vacuum tubes. Also, they are comparable in size, weight, and ruggedness with tubes having the same power-handling capacity. Since thermo-electron engines contain no moving parts, they are likely to be especially useful in remote applications where freedom from maintenance will give them a distinct advantage over conventional generating devices.

A typical thermo-electron engine based on a vacuum-diode element is shown in Fig. 1. Heat penetrates through a thin insulating tube into hot-plate emitter fins, covered on both sides by cold-plate collector cells. The cells can be connected in series to provide a higher voltage and a more practical impedance level for most applications. This design may produce up to 5000 W/cu ft and 25 W/lb at an efficiency of 10%.

The source of heat which can be used with thermo-electron engines may originate from the burning of fossil fuels, from solar energy, or from nuclear energy originating in radioactive isotopes or in fission reactions. Thermo-electron engines using nuclear or solar energy have the interesting characteristic of long useful life and small weight-to-energy ratio. Prototypes utilizing radioactive isotopes as the energy source are already being produced.

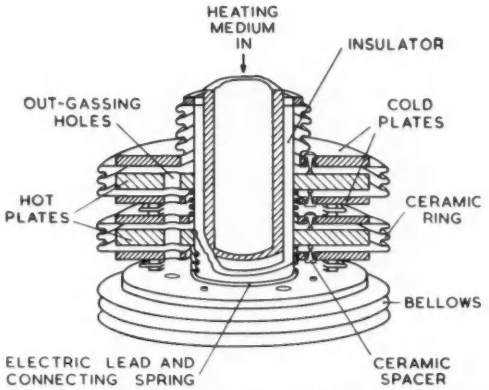



**Fig. 1. Constructional details of a vacuum-diode type of thermo-electron engine.**

Demonstration units and feasibility prototypes using natural gas for heating have been exhibited, and the first commercial versions will make their appearance in about a year. The commercial versions will be used to power small portable communications units and remote, unattended stations. They will also be incorporated in low-power household appliances and on mobile equipment as auxiliary power supplies. Applications to larger power requirements will follow rapidly.

The principle of operation of the thermo-electron engine can be seen from the simplified diagram in Fig. 2. Electrons are emitted from a heated electrode at a temperature $T_1$ and migrate to a colder electrode at a temperature $T_2$. In leaving the emitter, the electrons must do work equivalent to crossing the potential $\varphi_1$; on entering the collector, they give up a similar work $\varphi_2$. When the electrons migrate to the cold plate, they build up on the plate a negative charge which is observed as an output voltage $V_o$ between the plates.

In addition to the difference in potential given by $\varphi_2 + V_o - \varphi_1$, the emitted electrons must climb an adverse

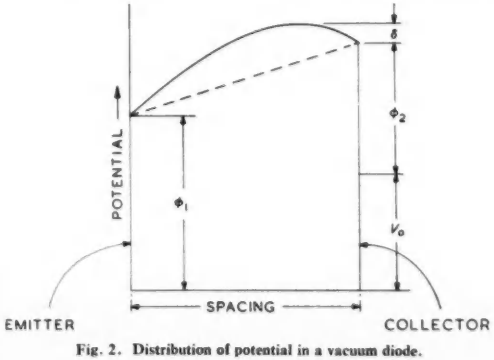



**Fig. 2. Distribution of potential in a vacuum diode.**

potential gradient which is caused by the electric field created by the electrons themselves in transit. This portion of the potential barrier, called the space-charge barrier $\delta$, must be reduced to a small value before useful power can be obtained. The principal technological problem is reduction of the space-charge potential barrier which prevents flow of a reasonable fraction of the emitted electrons.

There are three general approaches to the problem, i.e., (1) neutralization of charge by positive ions, using the gas diode, (2) an engine involving auxiliary electric and magnetic fields, using the magnetic triode, and (3) neutralization by close spacing, using the vacuum diode. The method of close spacing seems to offer the most immediate promise of practical usefulness. Present devices having a spacing of 0·001 in. or less produce about 1 W/cm² of electrode surface at an overall efficiency of better than 10%.

One approach to the problem of the neutralization of charge by positive ions, using the gas diode, is based on maintaining a caesium pressure in the collector-emitter space. If the work function of the hot emitter is higher than the ionization energy of the caesium (about 3·89 eV), then a large proportion of caesium atoms impinging on the emitter rebound as positive ions. This process of maintaining positive ions is inherently much more efficient than ionization by electrical means.

The use of an emitter with a uniformly high work function requires excessive temperatures to maintain practical current density. Thus, most recent designs call for a composite emitter which has some areas of relatively low work function supplying a copious emission of electrons, and some areas of relatively high work function supplying the required ions. It is hoped that a patchy tungsten surface, by its difference in work function between patches, will provide the required type of emitter.

There is a serious doubt as to whether effective mixing of electrons and ions will result at a patchy surface. The high work-function patches, which supply the ions, form at the same time potential traps which prevent the ions from spreading into adjacent areas of low work function from which the electron emission takes place. In order to prevent this trapping, a suggestion has been made to insulate electrically the adjacent alternate high and low work-function areas of the emitter and then bias them to counteract trapping.

This arrangement will probably consume power to maintain the required potential difference and consequently will provide additional power loss. Also, it is probable that from a certain distance a composite work function will exhibit an effect of an average work function; therefore, the effective emission of electrons, as well as ions, will be governed by this average work function. Thus, it appears that at present the caesium gas diode does not offer a clear-cut solution to the problem of space-charge neutralization.

The magnetic triode used in the second approach to the problem consists of an emitter, a collector, and an accelerating electrode, positioned as shown in Fig. 3. Electrons from the emitter are caused to follow an elongated cycloidal path to the collector by controlled electric and magnetic fields. The thermally emitted electrons absorb energy from the electric field as they rise above the cathode, but return this energy as they fall back towards the collector.

Ideally, no net energy is absorbed from the accelerating electric field. Likewise, no energy is absorbed from the magnetic field, since forces are perpendicular to the electron velocity. In the absence of space-charge effects and collisions with gas molecules, electrons arrive at the surface collector with the same energy with which they left the emitter.

Space-charge effects are both advantageous and detrimental. As an immediate consequence of space charge, potential distribution between cathode and accelerating plate is altered. Unless plate voltage is very high, there will be a point in the electric field near the emitter surface which has a more negative potential than the emitter.

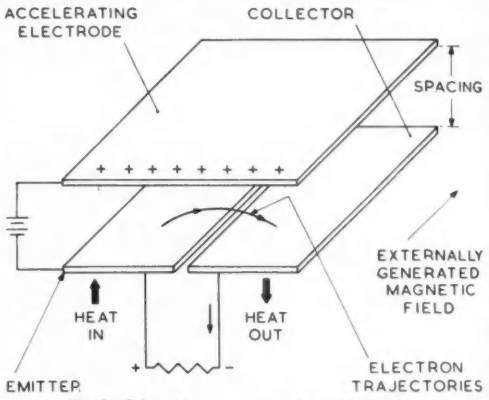



Fig. 3. Schematic arrangement of a magnetic triode.

Some of the current leaving the emitter surface can never penetrate this potential barrier. However, charges which do penetrate the barrier are all of a selected type in that they have a kinetic energy higher than the barrier energy. Thus, they can all enter a collector plate having a negative potential equal to this minimum energy. Since the accelerating plate voltage controls the height of the space-charge barrier, it is possible to select this potential equal to the emitter-collector (output) voltage.

If a practical magnetic triode could be constructed, it should have an efficiency greater than that of a diode of similar size by 50 to 70%, the difference mainly being due to the reduction in heat loss by direct radiation, the accelerating plate serving as a radiation shield between the two electrodes.

Present studies of the triode are directed towards understanding and controlling the flow of electrons from emitter to collector. A small current loss to the relatively high-voltage accelerating plate constitutes a power loss which is large compared with the power gained, even when a large current flows through the small output voltage. Since plate voltages are of the order of 100 V, and outputs of the order of 1 V, the fraction of the current reaching the plate must be less than 1% of that emitted just to break even in terms of net power production.

In the case of the third approach, involving neutralization of charge by close spacing, the vacuum diode used is the device which is most similar to that described by the principle of thermo-electron engine operation discussed previously (Fig. 2). The current density realized is inversely proportional to the electrode spacing, which must be kept small in order to obtain significant amounts of current and power in a device of reasonable size. Thus, a spacing of about 0·01 mm is required before a current density of the order of 1 A/cm² can be reached.

Tubes with such close spacing can nowadays be made, owing to progress in the manufacture of cathodes which

can be machined to close tolerances. However, the need for a method of supporting these electrodes to maintain their spacing creates a formidable problem. The problem is especially difficult because the support arrangement must conduct as little heat as possible, since heat conducted from the emitter is lost to the conversion process. Recent techniques utilizing the difference in the thermal coefficient of expansion of ceramic spacers and electrode materials have led to operational models in which tolerances of this order have been maintained with relatively little heat loss.

Close spacing effectively removes the adverse influence of the space-charge potential barrier. Greater power density can be obtained by an increase in emitter temperature $T_1$, or by a reduction in collector work function $\varphi_2$. The opportunity to raise the emitter temperature is limited by the availability of satisfactory materials; however, several materials which have substantially lower work functions than those currently in use are available.

It may appear that thermionic conversion is in competition with other direct conversion methods. However, because of its high operating temperature, the thermionic generator is an admirable complement to the other lower temperature generating schemes. A combination of thermionic and thermo-electric generator utilizing available practical equipment would have an overall efficiency greater than 15%.

# *The Present Status of*

# Vapour-Cooled Transformers

By P. Narbut and G. A. Monito

From *Westinghouse Engineer*, U.S.A.,
Vol. 19, No. 6, November 1959,
pp. 162–166, 7 illustrations

Cooling by evaporation is a remarkably effective method but, despite the considerable amount of experimental work devoted to development of vapour-cooling, a suitable liquid was not found until the advent of the new fluorocarbons shortly after World War II. With liquids satisfying the requirements for vapour-cooled transformers, work has progressed rapidly through the experimental stages to the point where commercial units have been installed.

Without question, the sealed dry-type transformer provides a higher degree of operational safety than any power transformer ever built. It has the advantage of being non-explosive, it is virtually fireproof, and it requires practically no maintenance. In addition, the dry nitrogen used as the gaseous dielectric and coolant can be lost without harm to the unit or to operating personnel. The only major drawbacks to the widespread use of the nitrogen-filled, sealed dry-type transformer are the limits imposed on voltage and power output by the gas. Nitrogen, at pressures up to one atmosphere, is not a sufficiently good dielectric or coolant to justify larger power outputs and higher voltage ratings, because the physical size and the cost of such units become prohibitive. Consequently, transformer manufacturers are attempting to extend the application of sealed dry-type transformers through the use of a better gas which will provide the necessary dielectric strength and more efficient cooling, while still retaining all the advantages of sealed dry-type transformers.

The new family of fluorocarbons offer nearly everything needed to extend the advantages and safety of sealed dry-type transformers to higher ratings, and are being investigated as dielectrics, as coolants, and as combined coolants and dielectrics, because of the remarkable properties they exhibit. Probably the most inert and non-reactive compounds known, they are poor solvents for most materials, and do not affect common insulating materials or metals; in fact, some insulating materials actually have a considerably lower ageing rate in fluorocarbons than in air. In addition, they are not only non-inflammable, but also have fire-extinguishing properties. The liquid fluorocarbon used to-day is non-toxic, odourless, and colourless, resembling water. Indeed, it can be handled as easily as pure water, but is less reactive.

The electrical properties of the fluorocarbons are equally unusual. Of specific importance, of course, is their dielectric strength. As a liquid, the fluorocarbon used has a dielectric strength of about 35 kV by standard tests, i.e., about the same as a clean, dry transformer. More important to this application, however, is its strength in vapour form. A comparison of air, sulphur hexafluoride, transformer oil, and the vapours of $C_7F_{14}$, a representative fluorocarbon, are shown in Fig. 1, in which it will be noted that, for the same pressure and electrode configuration, the fluorocarbon vapour has nearly twice the dielectric strength of sulphur hexafluoride, and five times the dielectric strength of air. The dielectric strength of the fluorocarbon increases with pressure, so that, at 15 psig, its dielectric strength is comparable with that of transformer oil.

## Fluorocarbons as Coolants and Insulators

Fluorocarbon liquids have certain physical properties that are especially valuable for vaporization cooling. Thus, they have extremely low viscosity and surface tension, which account for their ability to spread and readily wet coil surfaces and flow easily through minute crevices in the core. The high molecular weight of the liquid results in vapours of high density—an important aspect in vapour-cooling.

Using vaporizable fluorocarbon liquids, a relatively low rate of circulation is required to remove the heat generated in a transformer. The fluorocarbon liquids used in transformers are capable of removing about 10 kW of heat for every gallon per minute of evaporation.

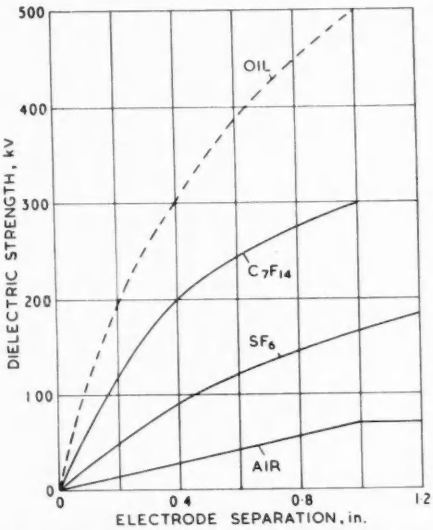



**Fig. 1. Comparisons of the dielectric strengths of air, sulphur hexafluoride, transformer oil, and $C_7F_{14}$, a representative fluorocarbon.**

The outstanding feature of vaporization cooling is its remarkable effectiveness. Generally, temperature gradients required at the surface for cooling by vaporization and condensation are small, compared with other modes of heat transfer. Thus, to transfer heat at the rate of 1 W/sq in. by natural convection and radiation from an open tank surface, the temperature rise of the surface over the ambient air must be around 90°C. For the same rate of heat transfer in oil by natural convection, the required temperature difference is about 15°C. Compared with the above, in heat transfer by condensation of pure fluorocarbon vapour the required temperature difference, vapour to surface, is only about 3°C, and, by boiling of fluorocarbon liquid on the surfaces, the required difference is only $\frac{1}{3}$°C. Consequently, one result of the use of vaporization cooling is inherently low internal temperature gradients, without the use of forced circulation of gas or vapour.

Still another interesting fact is that the maximum rate of heat transfer by boiling of a fluorocarbon coolant, before vapour locking will occur, may be in excess of 50 W/sq in. Admittedly, this value is many times higher than could be permitted in a conventional design of vapour-cooled transformer, but it serves to indicate that considerable non-uniformity in the wetting of the winding surfaces can be tolerated without ill effects.

Because of these unusual properties as coolants and as dielectrics, the use of the same fluorocarbon liquid as a vaporization coolant and as a combined dielectric has been suggested. This dual function would utilize the properties of the fluorocarbon to the best advantage and result in a fire- and explosion-proof transformer, thus permitting the extension of the safety features of sealed dry-type transformers to units of higher voltages and indefinitely larger power ratings.

The essential physical components required for vaporization cooling of transformers are shown in Fig. 2, in which a liquid fluorocarbon compound (indicated by shading) is applied over the top of the core and coils of the transformer, and flows down over all surfaces. Sufficient liquid is allowed to flow over the core and coils to ensure that only a portion of it evaporates, even under overload conditions. The vaporization process removes heat from the core and coils, the vapour (indicated by the outline arrows) then moving towards the cooler surfaces of the condenser and tank walls, where it condenses and gives up its latent heat. The liquid then flows to the bottom of the tank, where it is collected in a sump and recirculated by the pump.

With pure fluorocarbon vapour in the gas space of a transformer, the gauge pressure in the gas space would be equal to the vapour pressure of the coolant liquid. The temperature of the liquid would be substantially the same as that of the vapour, and the liquid would be at its boiling point corresponding to the tank pressure. Any addition of heat to the liquid will be likely to cause its boiling, and any removal of heat from the vapour will cause condensation.

Because of the high efficiency of heat transfer by condensation of pure vapour, all parts of the system in contact with the vapour tend to run at the same temperature; i.e., that of the vapour. The surface of the tank and the self-cooled coolers operate at approximately uniform temperatures from top to bottom, and thus at the peak of their cooling performance.

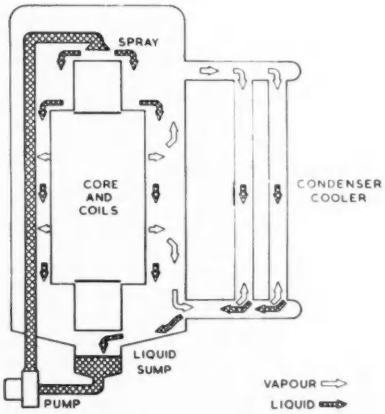



**Fig. 2. Arrangement of basic components required for the vaporization-cooling of transformers.**

With pure vapour in the gas space, there will be none of the familiar convection currents; the vapour will merely flow freely towards any part of the system from which heat is being removed (by external cooling), and will supply this heat by condensing back into a liquid. This method of heat transfer is especially suitable for remote installation of coolers, since only small pipe connections are required between tank and coolers.

Vapours of fluorocarbon coolants are an excellent insulating medium. However, to maintain their dielectric strength at the proper level, it is also necessary to maintain their pressure, and therefore their temperature, at the proper level. Although this does not take place in a normal transformer because of the load and ambient temperature variation, some of the unique characteristics of condensing vapours permit the design of a cooling system with variable cooling characteristics. With proper design, such a system would automatically maintain transformer temperature within design limits, in spite of the variable heat input, provided that a certain

minimum heat input is maintained, e.g., that of the iron losses alone.

While the use of fluorocarbon vapours alone as insulation has attractive possibilities, practical considerations have been a deterrent to such applications. In a commercial installation, such a transformer would have to be heated before it could be energized, to supply sufficient vapour for insulation purposes.

To overcome this difficulty, vapour-cooled units built so far have been filled with sulphur hexafluoride gas at low pressure. When the transformer is cold, sulphur hexafluoride is the principal insulating medium, because the vapour pressure of the cooling liquid is low. As the temperature of the transformer increases, the vapour pressure of the cooling liquid increases and, at operating pressure, the major insulating medium becomes the fluorocarbon vapour.

The use of sulphur hexafluoride is a compromise. Thus, while it resolves the problem of the cold start, this non-condensable gas reduces the efficiency of heat transfer, particularly by the condensation process. The result is that larger internal temperature differences appear, and larger cooling surfaces are required than would be necessary without sulphur hexafluoride.

With a non-condensing gas added to the vapour, the mechanics of vapour flow and the cooling characteristics are quite different. As the coolant percolates through the windings, it forms hot and heavy vapours, and these vapours mix to some extent with the $SF_6$ gas and generally flow downwards because of the high density of this vapour-rich mixture. The density of the mixture increases with temperature because of the high molecular weight of the fluorocarbon (416) compared with the $SF_6$ (146). Along the cooled surfaces, such as those of the cooler, condensation of the vapour takes place, and the mixture thus becomes richer in the $SF_6$ component and much lighter, and floats upwards. Thus, a definite circulation pattern of the gas-vapour mixture is established, the mixture flowing down near the windings in the tank, and up in the coolers. Because of the difference in densities, the circulating currents are vigorous; in fact, these natural circulating currents are sufficient to allow the use of standard self-cooled coolers for oil-immersed transformers with the 7500-kVA unit mentioned below. Without the vapours, i.e., with the $SF_6$ alone, normal convection through the coolers would be extremely poor, and the coolers would be practically useless.

The pattern of gas-vapour circulation is such that a peculiar situation exists with a vapour-cooled transformer, i.e., the lower parts of the tank and the lower parts of the cooler are the hottest, and the upper parts are the coolest.

## Field-Experience with Vapour-Cooled Transformers

Aside from several experimental vapour-cooled transformers, two commercial units are in operation in the U.S.A., and others are under construction.

The first of the two commercial units is a 500-kVA, 15-kV network transformer, first installed in the summer of 1957. The unit is compact in size, and has a high emergency overload capacity. Its performance was carefully checked during the first several months after installation, and the load, pressure, and temperature were monitored and found to agree with the performance curves furnished to the customer. A spot check after a total of eleven months operation indicated a deviation from the performance curves, and a superficial inspection indicated that the pump was not operating. However, there was no interruption of service, and the unit continued to carry load satisfactorily. Since a factory inspection of this transformer was originally planned after about a year of operation, the unit was removed from service at a convenient time. Inspection indicated inadequacy of the pump bearings, which were replaced by a different type. The transformer itself, in spite of operating for some time under normal load without a pump, was found in excellent condition, and is now in service again.

The second vapour-cooled transformer in service is a 7500-kVA, 34·5-kV residential substation transformer. Despite the relatively low pressure of insulating gas used, this unit has a full 200-kV insulation level, normally associated only with oil-immersed transformers. With external fans, the capacity of this transformer is 10,000 kVA and maximum operating pressure is well under 15 psig. The unit was placed in operation in July, 1958. After eight months of operation, the pump bearings were inspected and found to be in excellent condition, indicating that pump servicing—the only item which may require periodic attention—needs to be carried out only at long intervals, possibly once in several years. The bearings used in these pumps are lubricated by the cooling liquid itself.

In this 7500-kVA transformer, gas clearances, rather than solid insulation, are used, wherever possible, to provide the required insulation level. An inherent difference exists between gas and oil insulation. If the gas insulation is designed to be adequate to meet the full impulse requirement of an oil-immersed transformer, the insulation level required to withstand 60 cps will be considerably greater than that required for the oil-immersed transformer. As a result, a practical and economical approach would be to design to meet the required 60-cps level and permit a reduction in impulse strength consistent with the protection level afforded by the associated protective equipment. Thus, for example, on a 69-kV circuit protected by modern 60-kV arresters, a 250-kV full-wave insulation level is entirely reasonable.

Tests on the 7500-kVA transformer indicate that the cooling performance of the vapour-cooled system improves with load more than would be expected with an oil-immersed cooling system. An important parameter that may determine the load capacity of a vapour-cooled transformer is the operating pressure in the transformer tank. The pressure situation is complicated by the fact that the mixture is composed of a non-condensable gas and a vapour component whose pressure varies considerably with temperature; also, a continuous condensation process in the coolers and along the tank walls causes at least a partial segregation of the $SF_6$ in the upper part of the tank. Owing to these complications, the total pressure in the transformer tank is largely an empirical function of the vapour-gas temperature for the specific cooling structure. The 7500-kVA unit is designed for low-pressure operation. Thus, operating tests with this unit indicate that the tank pressure, even at 133% overload with fans operating and at 30°C ambient temperature, will be less than 13 psig.

In conclusion, it may be said that, while the vaporization-cooling of transformers has already proved practical, as evidenced by the commercial units built to date, the full potential of vapour-cooling has yet to be reached, and the inherent advantages of this type of unit may lead ot a much more widespread use of vapour-cooling in the future.

# *The Effects of Cutting Speed on Chip Deformation when Machining Aluminium Alloys*

By A. KARDOS

From *Acta Technica Academiae Scientiarum Hungaricae*, Hungary,

Vol. 26, Nos. 3–4, 1959, pp. 423–433, 12 illustrations

THE phenomena occurring when cutting aluminium cannot be explained by the theory of plasticity, and recourse must therefore be had to experimental investigations. While the problem of chip formation has been studied in the case of steel, the author is not aware of the existence of any research reports concerning this problem in the case of aluminium alloys.

This article, which deals with the effect of cutting speed on chip formation, describes a part of a series of detailed machinability investigations on extruded aluminium-alloy bars having a Brinell hardness of 61 kg/mm², a tensile strength of 23·8 kg/mm², and an elongation of 13%. The composition of the alloy is 2·8% Cu, 0·89% Zn, 0·45% Fe, 0·44% Si, and the remainder aluminium.

When the cutting speed is varied, the shape of the chips changes, influencing the tool life, the cutting force required, and the quality of the machined surface. The experiments reported here are therefore concerned with the relationships between cutting force and cutting speed, surface quality and cutting speed, and with a new method for determining the chip ratio, the formation of built-up edges, and the microhardness at the root of the chips.

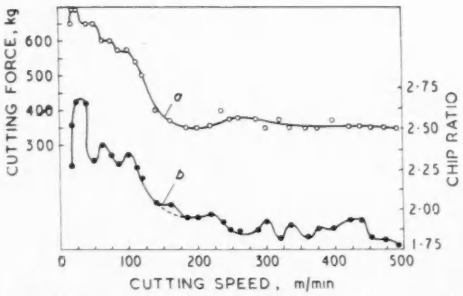



**Fig. 1. Cutting force and chip ratio as functions of cutting speed when machining an aluminium alloy.**

The cutting forces were measured with a special high-precision dynamometer in conjunction with strain gauges, and the chip ratio, i.e., the ratio of maximum to minimum chip thickness, was measured by a photographic technique, in which the differences in the cross-sectional area of the chips were obtained by photography and planimetering.

Fig. 1 shows the cutting force (curve (*a*)) and the chip ratio (curve (*b*)) plotted against cutting speed, for an average chip cross-sectional area of 3 × 0·4 mm². The curves obtained seem to contradict the assumption made by various authors that, in the case of aluminium alloys of the type used here, any variations in cutting force with cutting speed are insignificant. In this connection, however, it must be pointed out that the shape of the curves given in Fig. 1 has been verified by repeated experiments. In fact, it can be said that the general relationship between cutting force, chip ratio, and cutting speed of ductile aluminium alloys resembles that found with ductile steels.

Fig. 2 shows (*a*) surface roughness, determined with a profilometer, and (*b*) chip ratio, in this case estimated from the length of the chips, plotted against cutting speed, for an average chip cross-section of 1 × 0·2 mm². Here again, it is found that the relationship between these parameters is similar to that obtained with steel. Although a great number of experimental curves have been plotted, all of which were similar, the author does not consider sufficient data to be available for expressing the relationships between the various parameters mathematically. It seems clear, however, that variations in cutting force and surface roughness as functions of cutting speed can be explained by variations in chip deformation, and that the considerable forces required for cutting at low speeds, accompanied by an increase in surface roughness and chip ratio, are the result of the formation of a built-up edge.

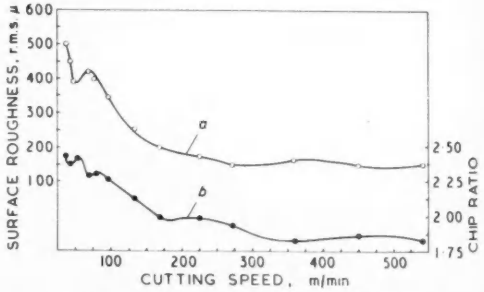



**Fig. 2. Surface roughness and chip ratio as functions of cutting speed when machining an aluminium alloy.**

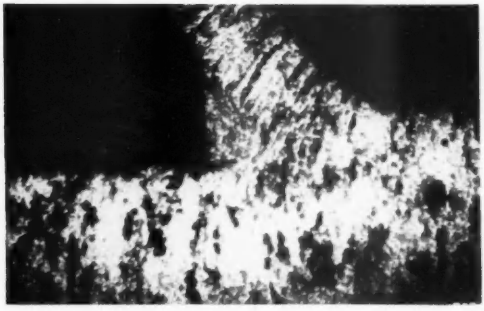


**Fig. 3. Photomicrograph of a typical aluminium-alloy chip root. (× 25)**

As distinct from the case of steel, the effects of the formation of a built-up edge when machining aluminium can be observed with the naked eye, and traces of a built-up edge on the tool can be shown to exist with all cutting speeds and chip cross-sections.

*(Concluded on page 106)*

# The Fatigue Strength of Sprayed-Copper Coatings

By J. Salokangas and P. Lehto

From *Acta Polytechnica Scandinavica*, Finland,
Mechanical-Engineering Series No. 6, 1959,

21 pages, 13 illustrations

In metal-spraying operations, the mean temperature of the metal spray is often quite low, since the spray is composed of a relatively small amount of atomized metal particles and a large amount of cooler gas. For a metal-sprayed coating to serve its purpose, i.e., as a protection against corrosion, it should be sufficiently dense and thick and, to ensure good bonding, thorough cleaning and roughening of the surface prior to spraying and correct operation of the gun during spraying are required.

Owing to porosity and oxide content, the structure of a sprayed-copper coating becomes heterogeneous. However, its wear resistance, its relatively high hardness, and its satisfactory bonding properties make copper a suitable coating material. Because of the porosity of sprayed-copper coatings, opinions differ regarding their ability to afford protection against corrosion, but the general opinion is that a machined copper coating, 1·5 mm in thickness, is sufficient to ensure perfect protection, against the ingress of moisture. Nevertheless, the occasional formation of cracks and the resulting troubles they can cause cannot be discounted, and have raised questions regarding the possible fatigue of sprayed copper and the factors influencing it.

Investigations into the fatigue of materials have shown that a heterogeneous structure is generally more susceptible to fatigue failure. On the other hand, such a material is rather insensitive with respect to external notching. In the case of a base metal such as steel, coated with copper, examination of the factors causing fatigue shows that it is to be expected that only detective points are susceptible to fatigue and are the starting points of possible failure. The capillarity of the pores has its own influence on fatigue, and this influence is greatest when moisture is allowed to penetrate the thin coating and to reach the steel base. The base layer between the steel and copper also has its own significance. Thus, if spraying is carried out in different ways, bonding is also different and it can therefore be expected that the smoothness of the zone between the base metal and the copper coating will have an effect on the fatigue strength of the whole.

In metal-spraying operations, there is a large number of factors which can affect spraying results and fatigue strength, factors connected with spraying proper including spraying distance, feed rate of the copper wire, pressures and mixing ratio of oxygen and acetylene, pressure of the atomizing air, and changes in the temperature of the specimen during spraying. Factors which can easily be altered, independently of other factors, are spraying distance and wire feed rate. Such factors as flame setting and the regulation of oxygen, acetylene, and compressed air separately and together have an influence on flow, atomization, and the nature of the flame, so that their arbitrary setting is out of the question.

For the purposes of this investigation, a rotating-bending fatigue testing machine, with a speed of 2840 rpm and a maximum bending moment of 600 kg-cm, was used. Based on the assumption that threading of the test bar is an acceptable and adequate method of preparing the base material for spraying, the test bar (Fig. 1a) used with this machine was provided with a thread, as shown in Fig. 1b. For preliminary tests, five bars were prepared, spraying being carried out in such a way that the gun remained stationary and the bar was moved in a plane which was at a constant distance of 3, 5, or 7 in. from the nozzle until a sufficient coating was built up, the bars then being machined to a cylindrical form, as shown in Fig. 1c. For final tests, ten bars of another steel (in this case, a 0·29% carbon steel with a Brinell hardness of 139) were prepared, these bars being sprayed while rotating between the centres of a lathe at a distance of 3, 5, or 7 in. from the nozzle of the gun, which was mounted on a carriage and moved by degrees until a sufficiently heavy coating was obtained. These bars were then machined to the same dimensions as those of the five bars used for the preliminary tests. Spraying was effected with a type of gun in which the copper wire is melted in an oxy-acetylene flame, atomization being carried out with the aid of compressed air. The oxygen pressure was 35 psi, the acetylene pressure 15 ps, and the air pressure 65 psi.

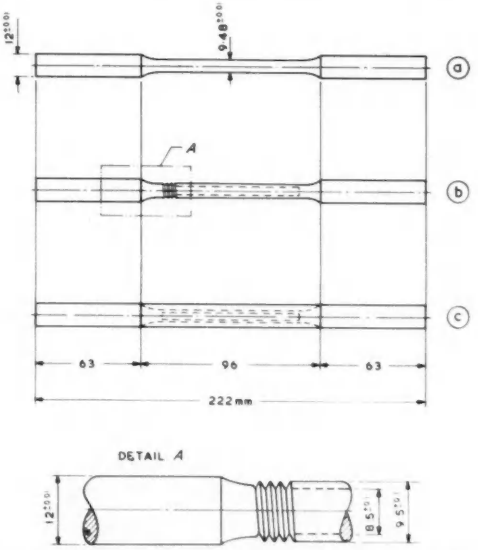



Fig. 1. Preparation of test bars used, showing (a) the normal test bar, (b) the threaded bar used for spraying operations, and (c) the sprayed bar.

In the case of the five bars used for preliminary tests, one bar was sprayed at a distance of 3 in. with a wire feed rate of 1·23 m/min, three bars at a distance of 5 in. with wire feed rates of 0·83, 1·14, and 1·43 m/min, and one bar at a distance of 7 in. with a wire feed rate of 1·23 m/min. Of the ten bars used for final tests, two were sprayed at a distance of 3 in. with a wire feed rate of 1·19 m/in, six at a distance of 5 in. with feed rates between 0·68 and 1·19 m/min, and two at a distance of 7 in. with a feed rate of 1·23 m/min.

Although the fatigue strength of copper is uncertain and tests should really be extended to $10^8$ cycles, it was decided to take $10^7$ cycles as the limit, owing to the slow-

ness of the fatigue testing machine. Even so, it should be appreciated that adequately comparable results for different spraying conditions were obtained, as it was not the purpose of the investigation to determine Wöhler curves for the sprayed bars, but rather to take the first signs of a crack in the sprayed coating, as discerned under a microscope, as the decisive factor. For this purpose, a binocular microscope was mounted near the bar and, by moving the carriage, the entire surface of the bar could be examined. The bending moment which could not be exceeded without causing visible crack formation in the copper coating after $10^7$ cycles was taken as the fatigue limit. The bending moment was used as a measure of the stress during the tests and, as the dimensions of all the bars were identical, the method could therefore be regarded as comparable. In the preliminary tests, the five bars were subjected to a bending moment of 105 kg-cm, and a comparative investigation was made of their strength as a function of the number of stress cycles for different spraying distances and wire feed rates, making it possible to ascertain the lines on which the final tests should be continued.

The microscopic investigations made it possible to follow alterations in the surface of the coatings. On the whole, it can be said that the surface was even, although the pores formed craters at some points, those bars which had been sprayed at low wire feed rates having the best surfaces. When the load approached the limiting value at which the coating fractured, dust-like particles, distributed either randomly or in rows, appeared on the surface of the copper, and the first visible fracture would then usually, though not always, appear near such a row of particles. When a visible fracture was noticed, it generally travelled from one crater to another, winding around the entire bar, but this crack formation did not mean that the steel base would always have fractured at this point under higher loads. In any case, the crack did not penetrate very easily right through to the base metal but appeared to remain, at least for some time, near the surface. The dust-like particles observed on the surface are explainable on the assumption that the pores are partly deformed during machining, and sprayed copper then enters into them and is subsequently pressed out under alternating stress. These sprayed particles then grind against each other in the surface layer, the results of this grinding action appearing as "dust" on the surface.

Although the metal-spraying operation can be considered a "cold" metallizing process, heat does, however, play a considerable part, as also do the dimensions of the testpiece. Thus, a large specimen can conduct heat over a wide range and has a cooling action; on the other hand, a small specimen tends to heat up and, although the temperature is too low to cause any alteration in the crystal structure of the steel, it is nevertheless sufficient to affect the stress condition of the specimen. Owing to the provision of the thread and the layers of sprayed copper, the steel is bonded to the copper during spraying. As, however, the copper layers and the steel base cool differently, the base may warp during spraying and, after machining, may be eccentric with respect to the coating. This was particularly noticeable when spraying was carried out at a distance of 3 in., this distance being, in fact, too short—at least for continued spraying—for test bars of the dimensions used. Indeed, although the sprayed-copper layers seemed sufficiently dense and strong, the steel suffered so much from the process that it broke before the fatigue life of the coating was reached.

When spraying at a distance of 3 in., it was noted that the most likely point of steel fracture was the end of the thread on the bar before rounding off to a shoulder of 12 mm in diameter, this being due to the fact that, during cooling, the thermal stresses tended to loosen the coating from the steel at the junction of the shoulders. Thus, a weak point, further aggravated by the notch effect of the termination of the thread, remained between the shoulders and the copper. It should also be noted that the effects of heat were also apparent in the case of one bar sprayed at a distance of 5 in., when the steel base also warped during spraying.

It was observed that, when a bar with a cracked sprayed coating was further stressed, the result was fatigue of the steel base, and the fracture also followed the thread.

It may be said that spraying distances, using a constant rate of wire feed, seem to be, within certain limits, inversely proportional to the fatigue strength. Similarly, for a given spraying distance, the rate of wire feed is also, within certain limits, inversely proportional to the fatigue strength. In connection with these conclusions, it will be appreciated that if, for instance, the rate of wire feed remains constant while the spraying distance is varied, conditions will change in the metallizing cone, an increase in spraying distance giving a larger coverage but a reduced particle impact on the base metal, and more rapid cooling. As a result, bonding of the particles to the base deteriorates, providing a possible explanation for the decrease in fatigue strength of the coating.

On the other hand, if the spraying distance is kept constant and the wire feed rate is varied, atomization takes place in a different way. Thus, if the feed rate is increased, the melting capacity of the flame is strained to the utmost, and may result in a coarse spray of macroparticles of copper; conversely, when the feed rate is reduced, better atomization is obtained, producing a more homogeneous layer better able to fill cavities in the base metal, resulting in a higher fatigue strength.

## The Effects of Cutting Speed on Chip Deformation when Machining Aluminium Alloys

(*Concluded from page 104*)

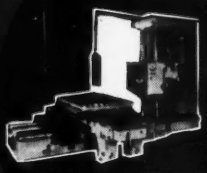
In order to produce chip roots for examination, the lathe was suddenly stopped and reversed, simultaneously withdrawing the cutting tool. The required portion of the workpiece was then cut out, polished, etched, and examined under a microscope. A typical photomicrograph of a chip root is shown in Fig. 3. Examination of all the photomicrographs obtained clearly showed the various stages in the formation of a built-up edge, the roughness of the machined surface, and its deformation, and established that the built-up edge consists of chip material only.

Microhardness measurements of chip roots were also made, and the results obtained clearly reflect the differences in deformation apparent in the photomicrographs and prove that the considerable hardness of the built-up edge is due to the influence of compressive stresses.

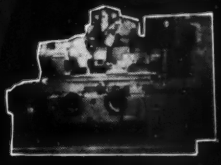
### *ERRATUM*

On page 481 of our issue for December 1959, the reference in the first paragraph to ", . . the range of 'Mechanics' universal joints . . ." should read ". . . the range of Moss universal joints . . .".

*The comprehensiveness of the range of fine machine tools by British, Continental and American makers sold by Charles Churchill enables a manufacturer planning production to cover his entire requirement from this one source, ensuring co-ordinated deliveries and the soundest technical advice. When production planning call in Charles Churchill and Company Limited.*



## PRODUCTION PLANNING WITH CHURCHILL



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# Lighting-3

Data Sheet No. 7 dealt with some actual applications of factory lighting. Further applications are given here.

### *Drawing Offices*

It is fair to say that in no part of a factory is good lighting more important than in the drawing office. The draughtsman's task is extremely exacting and unless the illumination is up to required standards, mistakes, loss of time and greater fatigue will result.

***The essential requirements are :***

High value of illumination
(*minimum of 30 foot-candles on the boards*)
Absence of shadows
Absence of reflection

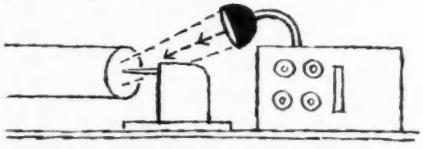
One of the major problems is the reflection of the light sources by shiny tracing paper, instruments, set-squares, etc., and particularly by the extra-hard pencil leads often used. Another problem is that caused by the shadows ahead of T-squares and by the variety of angles at which drawing boards are set.

Fluorescent lighting is particularly suitable because of its comparative freedom from shadow, its natural colour and because it can be localised with respect to drawing boards to avoid reflections while at the same time giving enough light upward and sideways to satisfy the general lighting requirements of the office.

A lighting solution which has been successfully employed for tracing is to light from beneath and through the paper which is fixed on to a translucent panel, thus eliminating the problems of shadow and reflection.

### *Machine Shops*

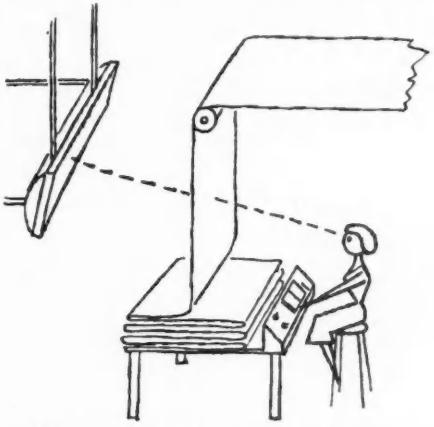
The problems of machine-shop lighting vary so widely that it is impossible to lay down rigid rules which are applicable to all types of machine. Much of the design of such lighting systems must therefore be a matter of individual application. Certain maxims, however, have proved in practice to be satisfactory in various trades.



There is a strong case for the provision of local lighting on many machines to enable the direction of light to be varied to suit the work, or to boost the illumination for fine work.

In shops employing certain machine tools, particularly circular saws, the possibility of stroboscopic effects can be avoided by splitting lamps among the phases of a three-phase supply or by using twin lamp fittings with a split-phase circuit.

Where safety goggles are used, extra illumination should be provided to compensate for the reduced light reaching the eyes.



Silhouette inspection of fabrics or profiles can often be used to advantage by placing a light source behind the material to be inspected — on the lines of the back-lighting already referred to for tracing in the drawing offices.

In general, machine-shop lighting is essentially an empirical science, based largely on a combination of general and local lighting, which offers immense scope for ingenuity.

### *Outside Lighting*

The outside precincts of a factory are often much neglected. No special rules can be suggested for lighting these areas, but speed, efficiency and safety are all dependent on adequate outside illumination during the hours of darkness.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each or 9/- post free) are available—" Lighting in Industry " is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including one on industrial lighting. Ask for a catalogue.

7932-2

# British Industrial Developments

## Automatic Welding Installation for Automobile Production

What is believed to be one of the largest single welding installations in the world has recently been supplied to The Pressed Steel Company at their new Swindon plant by the British Federal Welder & Machine Co. Ltd., of Dudley, Worcs. This equipment, which employs hundreds of individual projection- and multi-welding units, provides the entire welded production for the new Farina-styled B.M.C. range of automobiles, with an output of two assemblies per minute for each component. The equipment includes completely automatic conveyorized production lines which are used in the assembly of underbodies and doors, similar lines being used in the production of trunk lids and hood tops.

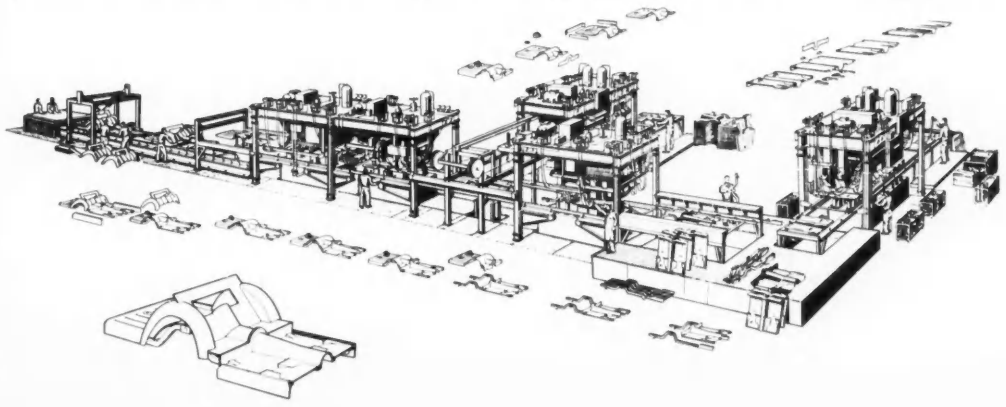
The illustration, which is an artist's view of the plant in operation, also shows the flow of component parts fed to the automatic line and the method of assembly of the underbody. A specially designed automatic shuttle system is employed for transfer of the components through the various multi-welding stations, sub-assemblies being fed into the equipment on side shuttles to form the complete assembly. In each welding position, between 100 and 200 welds are applied in a controlled firing sequence and, after ejection from the last welding station, the assembly is carried into a special fixture which automatically turns it over and transfers it to a conveyor, from which it is carried to the next operation. The use of this equipment has eliminated literally hundreds of standard and portable spot-welding units which would have been necessary with any existing known system, and production costs are appreciably reduced by automatic transfer and multi-welding. In each of the welding stations, accurate location is provided to ensure that the component parts are correctly located prior to welding, and hydraulically operated lift tables are incorporated in the welding stations to raise the assembly from the transfer shuttle to the welding station. An entirely interlocked electrical sequence controls the various movements, which are synchronized throughout the operation.

In the automatic door line of the installation, a number of small attachments are provided in the initial stages by means of standard spot- and portable welding units, a multi-welder press being used for pre-assembly of the main details to the separate panels. When this sub-assembly has been completed, the panels are placed together on an automatic transfer line and are automatically shuttled through five separate stations. In the first station a pre-clinch operation is applied between the outer and inner panels, in the second station these panels are multi-welded together, and in the third station the clinch operation is completed to close the outer panel edges rigidly to the inner panel. In the fourth station a table-top type of multi-welder is employed to provide a number of spot welds after clinching, and in the fifth station the assembly is ejected onto a conveyor. Only one operator is required at each end of this automatic line. The multi-welding fixtures used in this line employ a new technique which almost eliminates marking on the outer panels, thereby avoiding the necessity for final finishing operations.

The multi-welding equipment used on both these lines incorporates a number of new features, including high-speed indexing heads used for application of spots at close pitches, while specially designed electronic indexing timers built in the form of plug-in units are available for control of the firing sequence, so that the total load for the supply mains can be regulated within the capacity available.

In addition to these complex automatic lines, there are a number of conveyorized welding assemblies producing the smaller components of the body assembly; for example, a five-station conveyorized line is used for multiple spot welding of the heavy-gauge main side members, and a very large number of specially designed multiple spot-welding fixtures and projection-welding units are used for operations such as the welding of bonnet and trunk-lid reinforcements. A special fixture is included for the welding of the head-lamp reinforcement to the front fender, and a specially designed index stitch-weld unit has been included for welding the two half-panels forming the front and rear fender. A special fixture is used for welding the lamp-bracket reinforcement to the rear fender.

A special design of multi-welder is employed for welding wheel arches to the squab. This machine has hinged upper tooling, on which are carried the multi-weld



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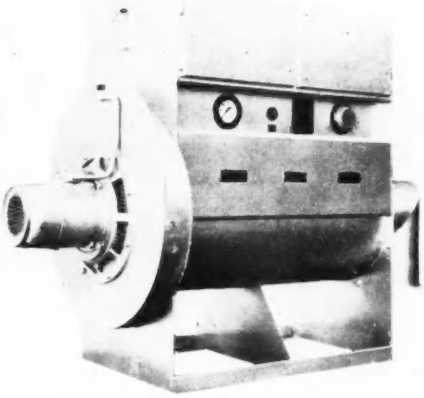
heads, transformers, etc., and this hinged tooling retracts to permit loading of several components onto the lower tooling, so that operators have free access to the specially designed dies and locators on the bed of the machine.

## Portable Electric Mould Dryers

Following an agreement with Brown Boveri & Co. Ltd., of Switzerland, Efco Ltd., of Weybridge, Surrey, announce that their subsidiary, The Electric Resistance Furnace Co. Ltd., are to manufacture portable electric mould dryers of the Brown Boveri design.

These dryers are widely used in European foundries for drying floor moulds and large box moulds. They operate by forcing hot air not merely over the mould surface, but through the sand itself, giving quicker and more efficient drying than is achieved with hot gases from fuel-fired stoves. Using air temperatures some 100° to 150°C lower than the hot gases, and less than one third the quantity of heat, they have reduced drying times by a half, and in some cases by two-thirds. Heating is extremely uniform throughout the mould and, despite the rapid drying, mould surfaces remain free from cracks, and cleaner castings are produced. The dryers need no attention during operation, power input being regulated automatically to maintain the desired air temperature. Working conditions are improved by the elimination of smoke and burning gases. Large cores can be inserted in the moulds and dried at the same time, the castings then being made without re-opening the moulds.



The drying equipment consists of an electric air heater, a fan and driving motor, and control gear, all of which is assembled into a single compact unit. The air is heated by being passed at great speed through ceramic tubes containing spiral-wound heating elements. The fan is fitted with a radially bladed impeller and a suitable diffuser, the impeller being mounted on a specially strengthened motor shaft, and the motor completely enclosed to protect it from dust and moisture. A single switch is used to bring the dryer into operation and to adjust the power input. The air temperature is controlled by a pointer-type mercury thermometer, with minimum and maximum contacts. A manometer measures the static pressure in the mould and indicates the density of the mould and the porosity of the sand. The mould to be dried is covered as for casting, and the dryer is placed in position over the casting gate. All openings, with the exception of the core and coke-bed ventilation channels, are closed. With the dryer in operation, hot air is forced through the mould sand, where it gives up its heat and passes out, saturated with steam, through the ventilation channels. The absence of steam indicates that drying has been completed.

These dryers will be manufactured by The Electric Resistance Furnace Co. Ltd. in three ratings, i.e., 25, 70, and 140 kW, and in two temperature ranges, one for use in grey-iron and other metal foundries where temperatures up to 350°C are sufficient, and the other providing temperatures up to 650°C for use in steel foundries. The 70-kW version is shown in the illustration.

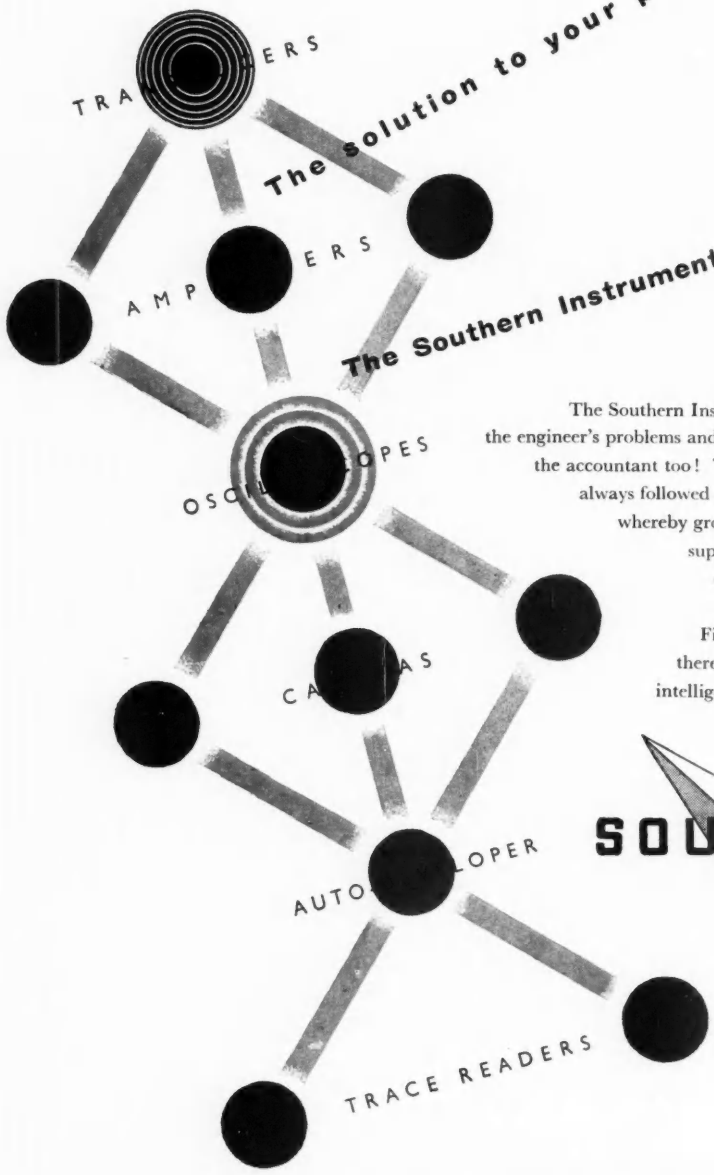
## High-Speed Electronic Data-Processing System

A new high-speed electronic data-processing system known as " Orion ", claimed to be one of the fastest and most powerful of its type in the world, is under development by Ferranti Ltd., of Hollinwood, Lancashire. Construction of the prototype is well under way and work has commenced on the first production models. The new system is fully transistorized and incorporates the latest " Neuron " logic elements, enabling complex systems to be built around the central computer with a minimum of components.

It is well known that a large computer is more economical than several smaller machines doing the same volume of work, and the problem has been to keep a large machine and its equipment working at full capacity. In the " Orion " system, this difficulty is overcome, as full facilities are provided for automatically sharing the time of the central computer between several programmes. This time-sharing system ensures that the computer is always fully engaged, even while peripheral transfers take place, and that peripheral equipment is kept working at maximum speeds, this being effected by special equipment which selects programmes according to given priority levels. This priority-processing is fully automatic.

Notable features of the system are automatic safeguards, known as lock-outs and lock-ins, which ensure that programmes in the computer cannot interfere with each other and which confine the programme in use to its own part of the computer. An unusually large number of different devices can be attached to the computer, with a unifying method of attaching them. In addition, transfers of information to and from peripheral equipment can be carried out concurrently, a new technique enabling this to be effected without using buffer stores.

The computer has a magnetic-core working store with a capacity between 1024 and 16,384 words, depending on requirements, this store being backed by a number of magnetic-drum units which are treated as peripheral devices. It will also have a comprehensive order code, with full facilities for automatic modification of addresses and for indirect addressing. Instructions will be of the two- or three-address type. The speed of addition and subtraction will be 36 to 68 microseconds, of multiplication 60 to 200 microseconds, and of division 300 to 900 microseconds. Fast floating-point operations will also be available. Magnetic tape will be processed at very high speeds. For example, 4,500,000 words per minute can be read or written by the computer. Various high-speed printers can be attached, including the " Xeronic ", which can produce up to 3000 lines of data per minute.

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Although smaller in size, the " Orion " will be up to 20 times faster than the " Perseus ", at present the largest data-processing system manufactured in Europe, and three to four times as fast as the " Mercury ", the fastest computer in Europe. Developed primarily for commercial data processing, the flexibility of the system makes it equally suitable for scientific research and technical calculations. Research and development of " Orion " has proceeded in parallel with " Atlas ", which is a large-capacity, very fast transistorized computer for scientific applications, at present under construction.

## Form-Dressing Attachment for Grinding Wheels

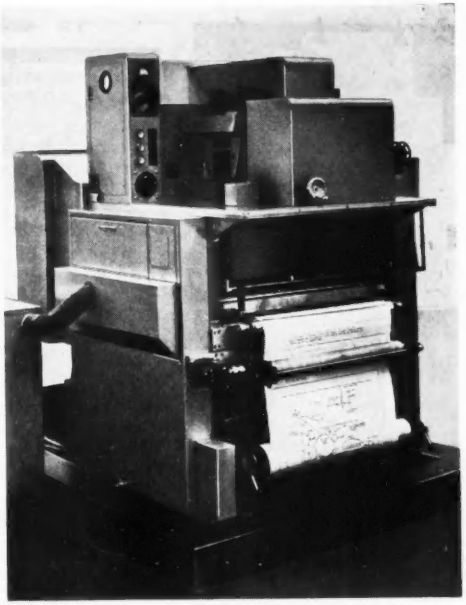
An attachment, developed by Precision Grinding Ltd., of Mitcham Junction, Surrey, as an auxiliary to their profiloscope, enables form-dressing of grinding wheels to be carried out without the use of master templates. The attachment, designated the " Optidress ", can be permanently fixed to the grinding machine and permits one radial and two straight-line motions to be effected in one setting. In addition, wheel form can be checked after dressing. A built-in microscope facilitates centring and positioning of the diamond and allows both the wheel and the diamond to be kept under constant observation while blending a radius into a tangential run-off. A graticule incorporated in the microscope carries radius markings from 0·025 to 0·375 in. in increments of 0·01 in., intermediate values of radius being approximated by means of a graduated scale.

The slide for dressing straight lines has a total movement of 1 in., traversed manually through a rack and pinion, and can be set to any angle from 0 to 180 deg. by adjustable stops and an engraved dial mounted on the microscope tube. This slide is also used for radial dressing by stopping it between two centralizing stops, which have been adjusted initially to bring the diamond into axis with the centre of the microscope. Thus, to dress a straight line, a radius, and another straight line, all that is necessary is to set the angular stops and to swing one of the centralizing stops out of position when changing from a radial to a straight-line movement. The microscope and dressing unit are mounted in co-ordinate slides, so that they can be brought into position in accordance with wheel diameter and width, and also assist in co-ordinating various operations to build up a profile of 1½ in. in length.

## Automatic Xerographic Microfilm System

Combining the advantages of microfilm, punched cards, and xerography, a " unitized microfilm " system, shortly to be installed in the Chelmsford headquarters of Marconi's Wireless Telegraph Company Ltd., provides a fully automatic method of document storage and reproduction and will produce for the company more than 1,500,000 prints per year. The system is based on the new Rank-XeroX " Copyflo " Model 5 automatic xerographic enlarging machine, used in conjunction with microfilm inserted in data-processing cards, and will substantially replace the conventional dyeline methods formerly employed, providing substantial benefits in economy, speed, and convenience.

In the new system, drawings and documents are microfilmed, and each frame of microfilm is inserted in



" Filmsort " aperture cards which are then coded by punching, so that they can be selected rapidly and filed manually or mechanically. In this way, great savings can be made in the space and time required for storing and finding the master-drawing microfilms. Copies of the drawings are made by stacking the selected master Filmsort cards in the Copyflo machine, which scans each card and, from the frame of microfilm, makes the required number of enlargements by automatic xerography. The Copyflo machine can produce prints at a speed of 20 fpm on ordinary, unsensitized paper, and is also capable of printing from roll microfilm and onto offset or dyeline master material.

## One-Coat Industrial Stoving Finishes

For many years, the firm of Lewis Berger (Great Britain) Limited has been synonymous with quality paints, enamels, and finishes, and in this connection it is interesting to note that their latest product is a new one-coat stoving enamel which is believed to be harder yet more flexible than any other on the market. Designated " Bergercron ", the new finish is manufactured by the company under licence from the Pittsburgh Plate Glass Company, of Pittsburgh, Pa., but is also the result of considerable original research carried out by the Berger laboratories at Dagenham, Essex.

Quite apart from its comparatively high hardness and flexibility, the new enamel, which is based on the use of acrylic resins, has excellent adhesion, extremely good corrosion resistance, very good colour stability during and after stoving, and the ability to provide a satisfactory finish on various metal surfaces with just one coat, no primers, or no undercoats. Bearing in mind that, among many other applications, it is intended for use as a finish on domestic appliances, such as refrigerators, food-mixers, and washing machines, it should be noted that comparative stain tests have been carried out with com-

## Do you wait for hot water on a cold Monday morning?

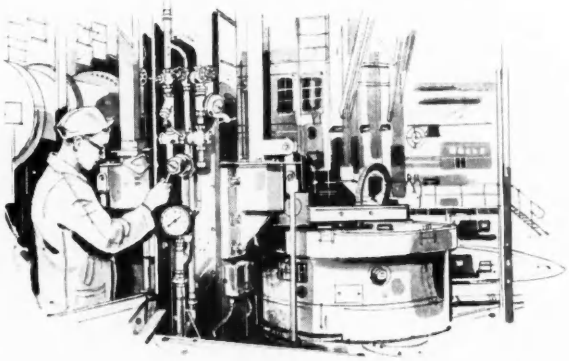
Where hot water is provided from a storage system there is a waiting period when production starts, for the water to heat up in the storage tanks.
With Leonard Steam Water Mixers there is no waiting period. Hot water is available as soon as the steam is turned on.

## How would you raise the temperature of a spray very gradually from cold to 120 degrees?

Leonard Valves fitted to the sparge pipe on a cloth scouring and milling machine enable the scourer to vary the temperature to suit the work and to make changes in the temperature during the process gradually, giving a cleaner scour and a better finish.

## Do you use cold water when you would like to use hot?

When vegetables are cleaned for canning they are washed in a running stream of water. If the water is too cold the girls' fingers get numb and their production slows down. If it is too hot the vegetables are spoilt. A Leonard Valve looks after the temperature, the girls' fingers and the vegetables.



These are specific examples. Your use of Leonard Thermostatic Steam Water Heaters will probably be different. Write for help. (Our folder H/24)

***WALKER CROSWELLER & CO. LTD.***

***Cheltenham. Telephone 56317***

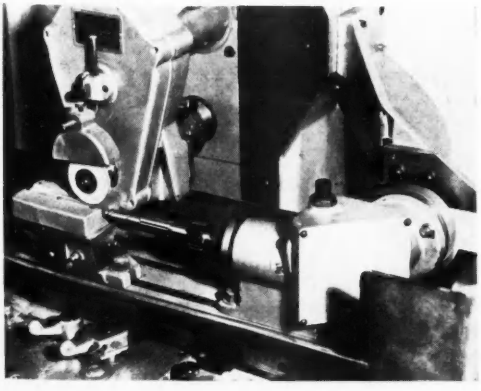
mon domestic substances, ranging from mustard, ink, and vinegar to detergents and even boot-polish, all of which are known to have marked staining qualities when left in contact with conventional appliance finishes. Tests with these materials on a 24-hr and 48-hr basis showed that the " Bergercron " finish remained completely unstained and unmarred in any way, whereas other finishes exhibited varying but noticeable degrees of discolouration, blistering, etc. Particularly outstanding is the resistance of " Bergercron " to a standard 2½% solution of detergent at 160°F for 48 hr; in addition, it will even resist a boiling detergent solution and is completely unaffected after a 30-min immersion.

To complete the range of tests on normal domestic " hazards " likely to be encountered in service, a representative of this journal suggested and carried out an additional test, involving leaving a cigarette burning on a " Bergercron " surface for three minutes, and finally stubbing out the glowing tip on the surface. In both cases, no permanent staining or other marring of the finish was noted.

The new finishes can be supplied in a variety of hardnesses and flexibility and are available in virtually any colour and any texture, ranging from matte to high gloss. Application can be effected by all normal methods, including dipping, roller-coating, flow-coating, and spraying, with particular reference to electrostatic spraying, while their ability to withstand stoving at very high temperatures without discolouration or detriment to the finish provides a considerable saving in production costs. The normal stoving schedule is 30 min at 350°F, but this can be varied over a wide range, i.e., from about 10 min at 400°F to 60 min at 320°F.

## Spline-Grinding Attachment

Basically intended for use with their standard Model-540 surface-grinding machine, a special spline-grinding attachment announced by A. A. Jones & Shipman Ltd., of Leicester, makes it possible to grind the radius at the bottom of 4-spline shafts with a formed wheel, automatically indexing the component through 90 deg. each time the machine table moves to the right and bringing the grinding wheel clear of the splines. As the clearance between the splines and the plain portion of the components is very limited, a small-diameter wheel is necessary, and a high-speed attachment carrying a wheel of 2½ in. diameter is attached to the wheelhead in lieu of the normal-size wheel.



The work is mounted on centres between a tailstock on the left-hand side of the table and the automatic indexing head on the right. The indexing head is actuated by a cam mounted on the side of the wheelhead column, contacting a ratchet lever and indexing the work spindle through 90 deg. A plunger engaging an index wheel retains the spindle in position during the grinding operation, and a driving plate on the front of the index-head spindle engages a driver attached to the work. To enable the components to be loaded between centres with the bottom of the spline in correct relation to the wheel, a loading device which ensures that the driver is correctly positioned for the purpose is used.

A wheel-truing device is included which consists of a mandrel carrying a diamond set to the required radius and which can be mounted between centres and swung through the necessary arc of movement to form the required radius in the periphery of the wheel. Setting collars are provided to enable the diamond to be set to the required degree of accuracy.

## Anti-Fouling System for Ships' Hulls

Preventing both fouling and corrosion of ships' hulls below the waterline, the " Toxion " system announced by the Cathodic Protection Division of F. A. Hughes & Co. Limited, of London, W.1, represents an entirely new concept of anti-fouling techniques. Basically, the system makes use of a highly toxic, though non-persistent, poison, dissolved in a liquid vehicle which is not soluble in water, and discharged by compressed air through small pipes fitted at selected positions on the hull. At the same time, an electrical field is created by applying a current which provides cathodic protection, and the poison, rising in the form of bubbles, is attracted to the hull. Distribution is accomplished by the positioning of the discharge pipes, aided by the polarizing effect of the liquid vehicle.

The " Toxion " poison has been specially formulated and is toxic to all types of marine fouling organisms, including weed. When it escapes from the hull, it hydrolyses to form harmless salts, eliminating the possible danger of building up undesirable concentrations in closed waters, whereas, by comparison, most conventional anti-fouling compounds are persistent and their effects in closed waters can be cumulative. Every effort has been made to ensure that the equipment used to discharge the poison is simple, easy to operate, and trouble-free. Thus, the small-bore dispersal tubes are made of high-impact rigid polyvinyl chloride, and cooled compressed air is supplied by a self-contained unit, while a pump with a micrometer adjustment meters the required quantity of poison and a control panel permits variations in the discharge to different outlets. Two large service tanks are provided, and the fact that the poison is soluble in kerosene, which is designated as a non-persistent oil, makes for economy of operation.

Because marine fouling organisms are most vulnerable at the time of settlement and then grow rapidly, the " Toxion " system is operated whilst the vessel is in port or at anchor. In order to ensure complete protection, discharge is normally started when the main engines are put at stand-by prior to entering port. The cathodic protection equipment, either by galvanic anodes or by impressed current, is operative at all times.

As an example of the efficiency of the new system, it may be mentioned that tests have been carried out on the

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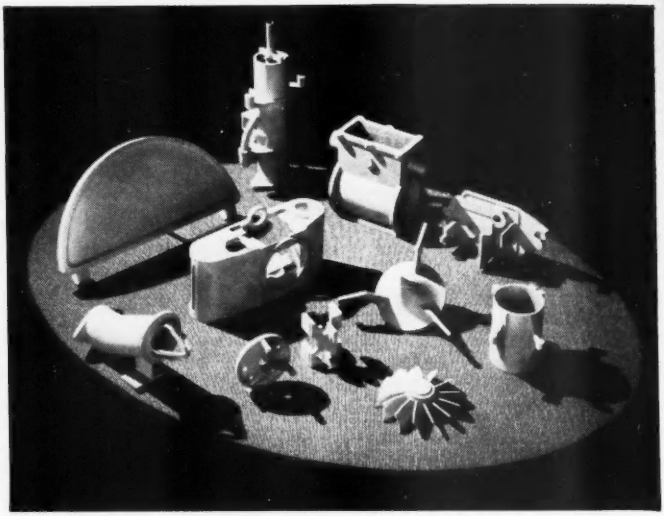

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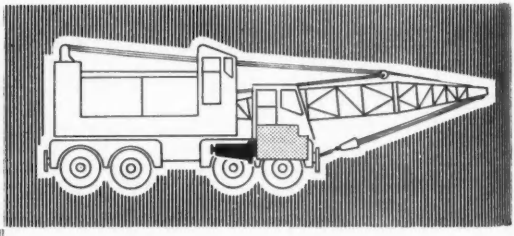

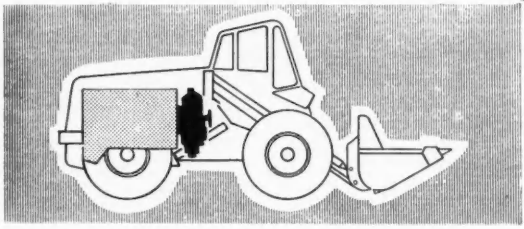

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P. & O. cargo-liner S.S. *Ballarat*, which plies between the U.K. and Australia and which was previously drydocked every five months approximately. At the end of a test of over six months, the ship was drydocked solely for examination and was found to be clean, except for very light grassing amidships between the light- and loaded-draft marks, whereas previously she had fouled badly after only five months on the same run. The ship later sailed again with the hull untouched and, after a further eight months in service, was again drydocked when, with the exception of a very small shell growth in a few shrouded areas, the previous findings were again confirmed. This growth was, in fact, already dead and could be removed with a soft broom, and the ship subsequently sailed again without any further treatment of the hull below the boot-topping, except for brushing and a little light scraping. It should be noted that, on future production systems, modifications are being made to reduce the slight shrouding effects mentioned, and even better results are anticipated.

## Automatic Soldering System for Printed-Circuit Boards

As announced by RCA Great Britain Ltd., of Sunbury-on-Thames, Middlesex, their associates in the U.S.A. are now offering an automatic soldering system for printed-circuit boards which eliminates the costly and time-consuming procedure of manual operation.

The main feature of this equipment is a multi-wave cascade solderer, which consists of a wedge-shaped block whose bottom surface is below the solder level of a large-capacity thermostatically controlled pot. Solder is pumped through a cavity in the block, so that a steady stream emerges and flows downwards in smooth uniform waves over four ridges on the surface of the block, which is sloped at 10 deg. and has side plates to prevent spillage over the edges. Since the fluxed boards pass over the block at an angle of 10 deg., they are always parallel to the block slope and are lapped by each of the four wave crests successively, providing complete coverage and permitting flux gases to disperse. With this cascade method, dross never comes into contact with the circuit board, but accumulates over the bulk supply, which it protects against further oxidation.

The pot, with a capacity of 450 lb, gives a very stable heat reserve and general pot level is not critical, provided that the bottom of the block is in contact with the solder. Flow is smooth and free from turbulence and produces an excellent finish, with bare spots, bridging, and tailing eliminated. No solder is forced through the holes for component wires, and the high operational speed of the unit and small contact area prevent damage to the board and its components and permit use of a high solder temperature for exceptionally clean results. The system requires only one operator to load and unload the assemblies, the production rate of the equipment being 600 finished assemblies per hour. The system applies flux, preheats the board, solders the assembly, and cleans off the excess flux, and is available as a complete unit, though separate components of the system can be provided for incorporation into existing facilities.

The complete unit utilizes a one-track conveyor system, around which the carriers or pallets move, spaced at regular intervals. A general-purpose pallet can be supplied and can be easily adjusted for boards of any proportions. The loaded pallets, which are pulled around the conveyor track by connecting links attached to a continuous chain drive, first pass through a foam of flux which thoroughly covers the copper circuits as the pallet passes across the bath. Controlled air jets in the liquid flux cause the foaming. This method has been found far more efficient than brushing, etc., since every portion of the circuit receives the proper amount of flux, regardless of the number of crimped lead wires. The pallet then moves over an electric, heat-controlled radiant plate, so that the flux becomes hot and tacky—a condition which improves the operational speed and quality of the soldering process. The heated pallet then advances over the multi-wave cascade soldering unit. The system is available in round, oval, horizontal, or vertical configurations.

## Welding Machine for Plastic-Coated Steel

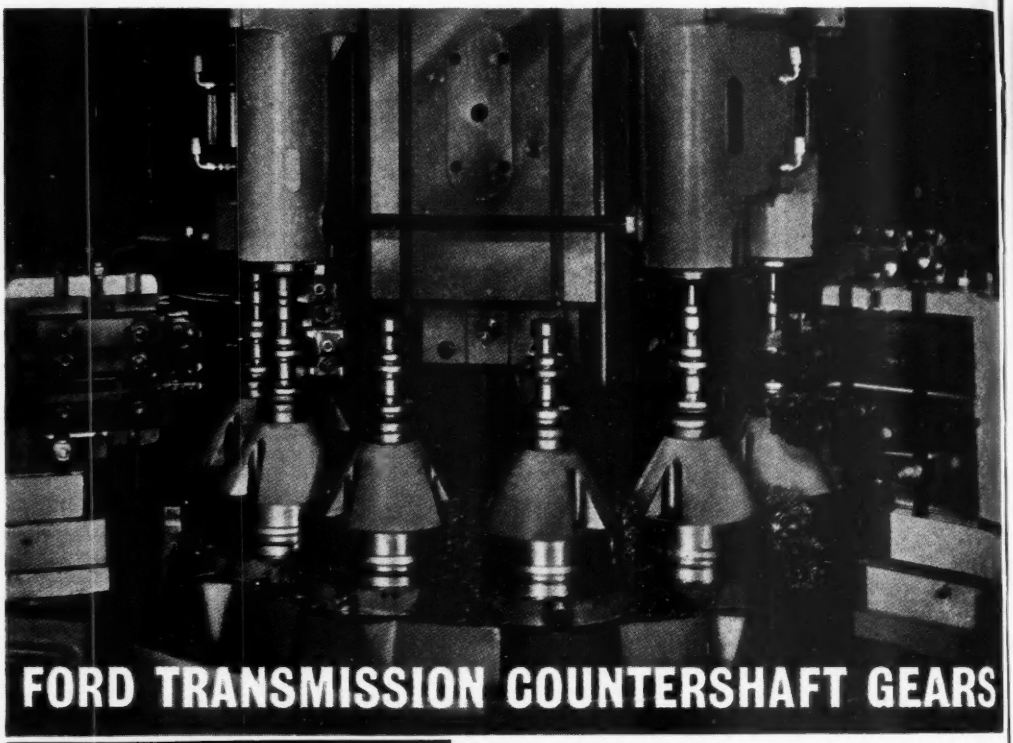
As a result of intensive research, Sciaky Electric Welding Machines Ltd., of Slough, have found that, by variation of the basic technique, heavily patterned and even simulated-leathercloth designs of plastic-coated steel can be satisfactorily welded, in addition to the more usual matte- and gloss-finished surfaces. Experiments have also shown that plastic-surfaced electro-zinc-coated steels can be welded as readily as mild steel. The result is the development of a commercially practical machine employing high-production methods and providing efficient welding with a high strength factor, but leaving the plastic surface free from indentation or burning. This machine has been delivered to a major motor-car manufacturer for welding plastic-coated dashboard assemblies on a new sports-car, but other possible applications include such items as metal office equipment, portable radio sets, and domestic appliances.

The new machine, designated Sciaky SAS 75, is a 75-kVA special-purpose projection welder operating on the series principle. The main frame is of rigid fabricated steel construction and contains the welding transformer and associated equipment. Hinged wing panels to the rear permit easy access for inspection and servicing. The top arm, work-supporting table, and lower arm are of heavy-duty construction and are bolted directly to the main stress members of the frame, providing the rigid structure essential for high-quality projection welding.

Unusual features of the machine include specially designed spring-loaded electrode assemblies to provide rapid follow-up, thus ensuring full consolidation of the weld nugget. These assemblies are individually adjustable for pressure and are provided with micro-adjustment mechanisms calibrated to permit critical settings to be made and accurately repeated. The head-assembly air-cylinder is fitted with a throttle to avoid damage to the projections on the workpieces during precompression.

The machine is fitted with a Sciaky fully synchronous electronic control unit which comprises a synchronous dekatron timer, phase-shift heat control, and an ignitron contactor, ensuring consistent repeat-weld conditions. The range of welding times is variable from infinity to 90 cycles, and the unit has a built-in memory device to control the $\frac{1}{2}$-cycle weld time required for this application, and to alternate the pulses of unidirectional energy on each subsequent weld, so as to prevent build-up of direct current and saturation of the transformer.

A number of existing Sciaky machines can be converted for welding plastic-coated steels and, with the continued expansion in the use of this material, Sciaky are investigating a " package-plan " conversion kit to adapt these machines.



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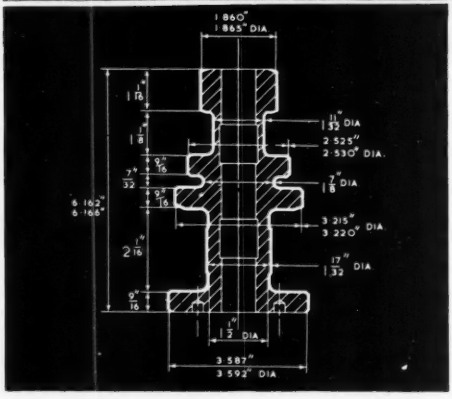


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# ADDITIONAL ABSTRACTS

*Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.*

## Methods of Cooling Oil-Immersed Transformers

By K.-H. NIEDERHOEFER
From *AEG Progress, Germany*, No. 4, 1958, pp. 273–283, 23 illustrations

MOST power transformers are of the oil-immersed type, the oil acting as an insulating medium and carrying away heat losses in the core and windings and giving them up to the external cooling medium, i.e., air or water. Cooling with natural circulation of oil is the simplest and most common method and can be applied to transformers up to about 25 MVA. With transformers rated at above 25 MVA, designed for no-load and short-circuit losses according to German standards, the number of radiators essential for natural cooling can no longer be accommodated on the tank walls, making air-blast cooling by means of fans essential. With air-blast cooling, the external dimensions of the transformer can generally be smaller than with natural cooling and, for ratings above 16 MVA, the cost of the air-blast equipment is more than offset by the saving in material, resulting in a lower transformer cost than with natural cooling. Moreover, the rating of a transformer can usually be increased by air-blast cooling with the addition of only a comparatively small amount of material.

In the case of large transformers, the heat losses, though comparatively small, are still large enough to oblige the use of a cooling system with a forced circulation of oil, generally in conjunction with air-blast cooling or water cooling. It is true that, if necessary, transformers with air-blast cooling but without forced circulation of oil can be built up to rated outputs of 100 MVA, but the specific weight [kg/kVA] in the case of such high ratings is higher than for a comparable transformer with forced oil circulation and water cooling.

The decision as to whether preference should be given to water cooling or air cooling is, in general, a question of economy and the space available at the time of installation, as well as transport conditions. In the case of transformers with forced circulation of oil, air-blast cooling is generally suitable for outdoor equipment, whereas water cooling can be employed in both indoor and outdoor installations; in addition, the lower temperature limits derived from water cooling result in lower copper losses, with a beneficial effect on transformer life.

## Production-Engineering Developments in the Soviet Union

By D. F. GALLOWAY
From a paper presented at *The Institution of Production Engineers, London*, December 10, 1959, 27 pages, 43 illustrations

GIVING some impressions obtained during a five-week tour of the Soviet Union, Poland, and Czechoslovakia by a delegation from the Production Engineering Research Association of Great Britain, this paper is mainly concerned with production-engineering research and development, general industrial development such as automation, and the engineering and scientific information services. Comments are also made on working conditions, wages, incentives, and general standards of living.

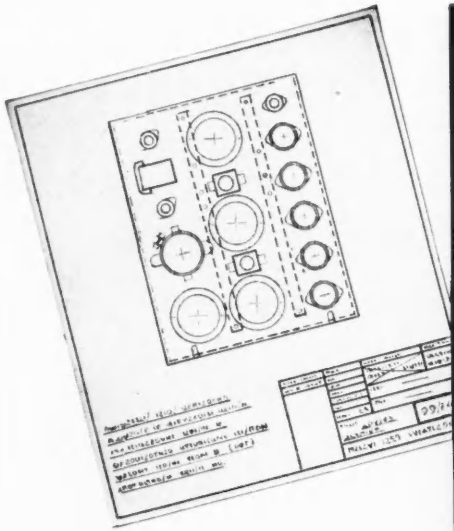
As the author points out, the Russian enigma cannot be solved by a single visit to the Soviet Union, but such a visit does provide a foundation of fact on which to construct a realistic assessment of present Soviet achievements and future Soviet potential. In particular, first-hand experience reveals industrial and scientific achievement of a very high order. The whole Soviet community is deeply involved in an intensive drive for higher industrial productivity, better standards of living, and an extension of Soviet influence in the world's economy. A struggle to become the world's leading industrial nation dominates all Russian life, and behind it lies the conviction of certain victory.

The Russian economy is clearly expanding at a rate never previously sustained continuously by a major industrial nation. Although Russia still has considerable leeway to make up in many industries, in housing, and in other aspects of standards of living, the tremendous advances of the past 40 years have accustomed all sections of the community to continuous rapid progress. Thus, an attitude of mind has been created which allows the momentum of the Russian drive to be maintained indefinitely without undue strain on managers, scientists, or workers. Present evidence suggests that the ambitious targets set by the current seven-year plan will be achieved, and hence the claim that by 1970 the Soviet Union will rank first in physical volume of production and production per head of population should not be ignored.

Production-engineering research and development are making a major contribution to the rapid advance of many branches of Russian industry, and widespread recognition of the practical and economical importance of such research has led to demands from managers and engineers in industry for a further expansion of Russia's already massive production-research facilities.

Britain, the U.S.A., and other Western countries can only meet the challenge which Russia's tremendously vital industries now present by providing every assistance and every incentive to their own industries to raise productivity by the continuous improvement of production techniques and equipment. In the widest context, this will demand an extensive re-appraisal of the present situation by governments, managements, scientists, engineers, workers, and workers' representatives.

Russian progress should be regarded not as a threat but as a challenge, which, if met, will lead to higher standards of living and greater security than Britain has ever known before.



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## Synthesis of Epicyclic Gear Trains, using the Velocity-Ratio Spectrum

By R. C. Brewer

From a paper presented at the annual meeting of *The American Society of Mechanical Engineers* in Atlantic City, N.J., November 29 to December 4, 1959, 6 pages, 10 illustrations

There exists very little literature to serve as a guide to those who wish to design an epicyclic gear train capable of satisfying a number of given conditions. In the field of linkage mechanisms, de Jonge has repeatedly stressed the undue emphasis which has in the past been placed on analysis to the exclusion of synthesis. This is also true in the field of epicyclic gear trains but, in this case, it has also led to a state of almost complete ignorance regarding the way in which compound epicyclic gear trains work; in fact, an examination of a number of American and British standard textbooks has failed to disclose any kind of explanation of the action of compound gear trains.

With gear trains, as with other mechanisms, it is normally true that synthesis presents more problems than analysis and, apart from the fact that there is rarely a unique solution, the method of approach usually has to sacrifice some elegance for the sake of expedience. The object of this paper is therefore twofold, i.e., (1) to give some conception of the working of a compound epicyclic gear train, and (2) to provide a method of synthesis which enables the design of such trains to be placed on a more rational basis. In the present discussion, consideration is limited to trains having annular or ring wheels, but the treatment itself is general and could be altered to suit other types of epicyclic gear train.

For a simple epicyclic train, the controlling element is almost invariably fixed, i.e., prevented from rotating by being connected in some way to the frame. Such trains are easy to synthesize because there is a limited number of variations of the three basic elements and, normally, six equations will define all possible velocity ratios. For a compound epicyclic train, the number of equations is considerably increased. The method of synthesizing compound epicyclic trains described in this paper uses the concept of a velocity-ratio spectrum. To facilitate the application of this concept, only one train in a compound epicyclic train is regarded as basic; all others are considered as merely serving the purpose of modifying the motion of the controlling element in the basic train.

## Relation between Critical Alternating Propagation Stress and Crack Length for Mild Steel

By N. E. Frost

From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, November 1959, 19 pages, 16 illustrations

The experimental determination of the fatigue strength of a specimen containing a notch or discontinuity has been the subject of considerable work. It is generally accepted that the geometric elastic stress-concentration factor $K_t$ is equal to or greater than the ratio $K_f$ of unnotched to notched fatigue strengths (considering only the simple and unambiguous case of zero mean load), the difference between them increasing as the value of $K_t$ increases. In addition, there is a so-called "size" effect, in which, for a series of geometrically similar notched specimens of differing sizes, although $K_t$ is constant, the larger is the specimen tested the nearer will the value of $K_f$ obtained approach that of $K_t$. Also, for identically shaped notched specimens, testing in rotating bending appears to give a higher fatigue strength than that obtained by testing in reversed direct stress.

In much of the past work, interpretation of experimental results has been confused, owing to the fact that the notched fatigue strength was based only on unbroken and completely broken specimens. This occurred because most of this work was carried out with cylindrical-type specimens, on which additional information is difficult to obtain. However, some investigators have found that cracks can form at the root of the notch in such specimens of mild steel, which at the stress level employed did not propagate to cause complete fracture, and this has been confirmed by the author using similar specimens of both mild steel and aluminium alloy and also edge-notched specimens of mild-steel plate. It has been shown that a crack forms at the notch root when the nominal stress is very nearly equal to the plain fatigue limit divided by the appropriate value of $K_t$, but that the crack does not continue growing until a certain threshold stress level is applied. Consequently, the simple idea of a fatigue strength or limit of a notched specimen being based on either broken or unbroken specimens must be supplemented by the fact that a specimen may be unbroken but cracked. In such a case, the stress required to propagate the crack will determine whether or not the specimen breaks, the sharpness of the notch being of no consequence. However, the depth of notch will now be of importance, as it is suggested that the overall crack length should include the initial depth of notch.

This paper discusses how the factors governing the subsequent propagation of a fatigue crack may be used to correlate the behaviour of notched specimens. The experimental work described is confined to mild-steel specimens containing edge cracks of varying length, and on which fatigue tests have been carried out and the alternating stress which is just sufficient to cause the cracks to grow has been obtained. The conclusions derived from this investigation may be summed up as follows:—

(1) The limiting alternating stress required to propagate a crack in mild steel at zero mean load is governed by the parameter $\sigma^3 l$, where $\sigma$ is the nominal alternating stress [tsi] and $l$ is the crack length [in.]. For crack lengths which are small in comparison with the specimen width, nominal stresses are based on gross area; a correction is necessary for such stresses when the crack length is an appreciable fraction of the specimen width. For edge cracks in mild steel, $\sigma^3 l = 5{\cdot}5$.

(2) For values of tensile mean stress such that the crack remains open throughout the loading cycle, the value of the parameter is modified so that $\sigma^3 l = 5{\cdot}5/8$, where $\sigma$ is the nominal alternating stress on the open crack. For other values of mean stress, $\sigma$ may be taken

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as the alternating stress component of that part of the loading cycle for which the crack remains open. (3) The alternating stress required to initiate a crack at the root of a notch is given very nearly by dividing the plain fatigue limit by the geometric elastic stress-concentration factor $K_t$. Whether or not such a crack will propagate depends on the value of the parameter $\sigma^3 l$, where $l$ now includes the notch depth.

One point that requires emphasizing is the effect of machining the notch on the resulting fatigue strength. Local work-hardening and the introduction of residual stresses at the notch root can make serious differences to the results and, unless extreme care is taken in machining and, if possible, a complete stress-relieving heat treatment given, some doubt must always exist regarding the validity of any experimental results obtained.

## Design and Materials for Reduced Pump Corrosion

By J. E. Piccardo
From *Corrosion, U.S.A.*, Vol. 15, No. 9, September 1959, pp. 41–44, 8 illustrations

Of the pumps used in the chemical and allied industries, about 90% are of the centrifugal and diaphragm types. These pumps are required to handle corrosive liquids under conditions of high pressure and high temperature, expensive or hazardous liquids where leakage to atmosphere cannot be tolerated, liquids with solids in suspension, often of an abrasive nature, creating both corrosion and abrasion problems, and extremely corrosive liquids which may be radioactive.

Diaphragm-type pumps have certain advantages over centrifugal pumps for severe chemical applications because there is no shaft-sealing problem, solids in suspension can be handled at relatively low velocities, and a high degree of corrosion resistance can be obtained by the use of high-alloy steels for the pump body and of synthetic materials for diaphragms.

Packingless pumps include the so-called canned-motor centrifugal pump, in which the pump impeller is mounted on the same shaft as the rotor. Both the rotor and the stator are sealed from the fluid by corrosion-resistant cans or shields, and the rotor moves in the liquid being pumped. The rotor-impeller shaft is supported on sleeve-type bearings submerged in the liquid pumped. Canned-motor pumps usually cannot be applied where the liquid contains solids, because of close clearances and possible damage to bearings by abrasion.

Designs giving longer service life in the conventional centrifugal pump usually include improved sealing devices where the pump shaft passes through the casing, new alloys or metals for the wetted end to provide a better corrosion resistance, and improved elastomers, plastics, and ceramics which permit lining entire pumps for a high degree of corrosion resistance. Improved shaft seals are also discussed, together with a study of new materials available for pump parts, and linings for pumps commonly used in chemical pumping service.

## The Photovoltaic Effect and its Utilization

By P. Rappaport
From *RCA Review, U.S.A.*, Vol. 20, September 1959, No. 3, pp. 373–397, 21 illustrations

As the need for power becomes greater and conventional energy sources, such as fossil fuel and fissionable materials, are used up, the direct conversion of solar energy could become an important source of power. A major step towards the solution of this difficult problem has been achieved by the solar converter or photovoltaic cell. These devices are sometimes called solar batteries, but the term battery is incorrect, strictly speaking, since the primary energy source is not self-contained. Cells have already been made that can convert the sun's radiated energy directly into electrical energy with an efficiency of up to 14%, which is the best experimental overall efficiency reported to date for any artificial conversion method.

In this paper, which presents a review of the theory and application of the photovoltaic effect, with special emphasis on solar-energy conversion, the development of this effect from an interesting scientific phenomenon into one of the most efficient methods yet devised for converting solar energy directly into electrical energy is described, and attention is given to considerations of the optimum semiconductor material for solar-energy conversion and how it changes with operating temperature. Experimental results are presented which show the operating characteristics and conversion efficiencies of a number of materials, including silicon, gallium arsenide, indium phosphide, cadmium sulphide, and others. The high-voltage (about 100-V) photovoltaic effect obtained with evaporated CdTe films is described, and a discussion of the major problems still to be solved is included.

Quite apart from their high efficiency, photovoltaic cells have the advantage of unlimited life and of being easy to fabricate, as they are one of the simplest of semiconductor devices. In addition, they have a high power/weight ratio, making them eminently suitable for satellite applications. Thus, cells with an efficiency of 10% can yield 50 W/lb on the ground in sunlight of 100 mW/cm², and about 12·5 W/lb in sunlight of 135 mW/cm² on a satellite, where tumbling, rotation, cell matching, higher temperature, light losses in cover, and other factors are taken into account. Furthermore, these cells do not require high temperatures for high efficiencies, thus eliminating lenses and concentrators in all but very special applications. The two main disadvantages to date are their high cost and the need for a storage device.

In the near future, silicon solar cells should be available with efficiencies in the 15% range. Cells using other materials or combinations of materials should be capable of 20% conversion efficiency, and large-area polycrystalline films in the square-foot range might yield 5% efficiency. Such devices should present very strong competition in the field of solar-energy conversion to new and promising thermo-electric or thermionic devices now under development.

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## New Method of Lubricating the Crankshaft Bearings of Internal Combustion Engines

Essentially comprising the timed injection of oil into bearings at a pressure of about 900 psi, so as to clear cavitation before they are subject to peak loading, a new method of lubricating the big-end and main bearings of internal combustion engines announced by The Glacier Metal Company Ltd., of Alperton, Middlesex, is stated to improve their life and load-carrying ability and to make it possible to increase engine speed or to use higher pressures.

Designated " Ramrod ", the new method stems from fundamental research carried out by The Glacier Metal Co., who have constructed a special test rig which can simulate all the loads imposed on the crankshaft bearings of either a four-stroke or a two-stroke engine. Because the material in the rig is transparent, the behaviour of the film inside the bearing can be observed directly and recorded. In this bearing oil-film analyser (Fig. 1), polar load diagrams can be followed by cams set out on the left-hand panel, and the corresponding loads applied in two planes by cylinders acting on the transparent bearing, in which a shaft rotates at 7 rpm, i.e., at about 1/70th of the true engine speed. For this reason, to provide conditions which are comparable with those in an actual engine, the oil-pressure and bearing loads in the test rig are reduced by a factor of about 15 and the oil viscosity is increased by a factor of about 5.

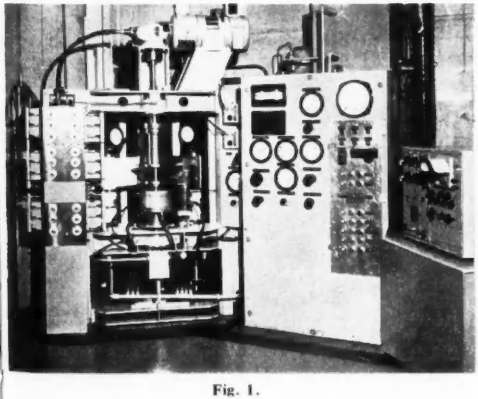

Fig. 1.

The test rig clearly shows that, irrespective of the position of the oil-delivery hole in relation to the peak of the cyclic load, i.e., on the firing stroke, cavitation forms in the bearing in the region of maximum clearance, as shown in Fig. 2, and this area of cavitation rotates at half the shaft speed. As a result, cavitation is present on the pressure side and the bearing material receives the full force of the explosion at a moment when only a fraction of its area is protected by the oil film which is supposed to separate it from the crankshaft, leading to a well-known type of bearing failure which is typical of incomplete lubrication through cavitation. The " Ramrod " system therefore is intended to ensure that the empty space caused by cavitation is filled with oil, and—a particularly important point—this always occurs before the firing load. In other words, a complete oil film is established before the thrust is applied, as distinct from the conditions prevailing in conventional lubricating systems, in which, despite the use of an adequate oil pump and generously dimensioned oilways through the crankshaft, the surfaces lie nearly naked at the precise moment when they are subjected to the most severe conditions.

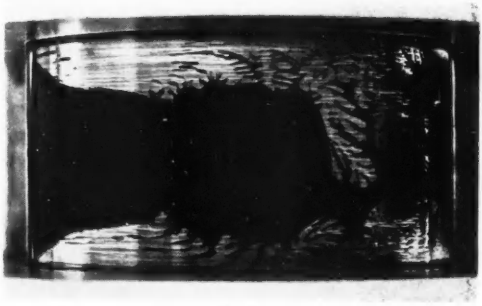

Fig. 2.

As a result of the improved lubrication conferred by the " Ramrod " system, it is stated that it is possible to use shorter bearings, with a consequent stiffening of crankshafts by reducing their overall length. For this reason, engines can be produced which are shorter, lighter, and cheaper for a given power than any at present practicable. Furthermore, the system is mechanically simple and can be provided at a cost which still provides substantial savings in the overall cost of a given engine.

## The NSU-Wankel Rotary Internal Combustion Engine

Details have recently been received from NSU (Great Britain) Limited, of London, W.1, of the NSU-Wankel rotary internal combustion engine, which has only two moving parts, i.e., a rotor and an output shaft to which the rotor is suitably geared, and which eliminates the need for the valves, valve springs, camshafts, and almost all the other complications and refinements of reciprocating piston engines. The new rotary engine owes its origin to the work of Felix Wankel, and its development dates back to 1951, when NSU began to collaborate with Wankel. However, during 1959 a considerable contribution has been made by the Curtiss-Wright Corporation

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Types and Performance Data

| Type | No. of cylinders / Arrangement | Output P.S (DIN) | Speedrange R. P. M. | Cyl. Bore ins. | Stroke ins. | Piston displacement cu. ins. | Weight approx. lbs. |
|---|---|---|---|---|---|---|---|
| M 202 B | 2 / S | 35— 55 | 750—1200 | 5 1/2 | 8 1/4 | 394.8 | 1665 |
| M 203 B | 3 / S | 54— 96 | 750—1200 | 5 1/2 | 8 1/4 | 591.9 | 2150 |
| M 204 B | 4 / S | 72— 126 | 750—1200 | 5 1/2 | 8 1/4 | 789.0 | 2715 |
| OM 636 | 4 / S | 17— 35 | 1500—3000 | 2 15/16 | 3 11/16 | 107.8 | 495 |
| OM 312 | 6 / S | 47— 77 | 1500—2400 | 3 5/8 | 4 3/4 | 279.5 | 990 |
| OM 321 | 6 / S | 55— 94 | 1500—2600 | 3 1/4 | 4 3/4 | 311.2 | 1025 |
| OM 315 | 6 / S | 80— 124 | 1200—1800 | 4 1/16 | 5 1/2 | 505.0 | 1875 |
| OM 326 | 6 / S | 97— 155 | 1200—1800 | 5 1/64 | 5 1/2 | 660.0 | 1720 |
| MB 846 A | 6 / S | 114— 250 | 750—1500 | 5 7/8 | 7 1/2 | 1230.2 | 3860 |
| MB 846 B | 6 / L | 114— 250 | 750—1500 | 5 7/8 | 7 1/2 | 1230.2 | 3970 |
| MB 846 Ab[1] | 6 / S | 148— 320 | 750—1500 | 5 7/8 | 7 1/2 | 1230.2 | 4080 |
| MB 846 Bb[1] | 6 / L | 148— 320 | 750—1500 | 5 7/8 | 7 1/2 | 1230.2 | 4200 |
| MB 846 Ad[2] | 6 / S | 148— 320 | 750—1500 | 5 7/8 | 7 1/2 | 1230.2 | 4200 |
| MB 836 B | 6 / S | 230— 350 | 1000—1500 | 6 7/8 | 8 1/16 | 1806.3 | 4380 |
| MB 836 Bb[1] | 6 / S | 305— 500 | 1000—1500 | 6 7/8 | 8 1/16 | 1806.3 | 4830 |
| MB 836 Db[1] | 6 / S | 370— 650 | 1000—1500 | 6 7/8 | 8 1/16 | 1806.3 | 5050 |
| MB 820 B | 12 / SV | 460— 700 | 1000—1500 | 6 7/8 | 8 1/16 | 3612.6 | 6180 |
| MB 820 Bb[1] | 12 / SV | 610—1000 | 1000—1500 | 6 7/8 | 8 1/16 | 3612.6 | 6900 |
| MB 820 Db[1] | 12 / SV | 770—1350 | 1000—1500 | 6 7/8 | 8 1/16 | 3612.6 | 7240 |
| MB 837 A | 8 / SV | 165— 440 | 850—2000 | 6 1/2 | 6 7/8 | 1825 | 2940 |
| MB 837 Aa[1] | 8 / SV | 240— 550 | 850—2000 | 6 1/2 | 6 7/8 | 1825 | 3020 |
| MB 839 Ab[1] | 16 / SV | 1145—1800 | 1000—1500 | 7 1/2 | 9 1/16 | 6380 | 11020 |
| MB 839 Bb[1] | 16 / SV | 1380—2350 | 1000—1500 | 7 1/2 | 9 1/16 | 6380 | 11450 |
| MB 518 [1] | 20 / SV | 3000 | 1720 | 7 1/16 | 9 1/16 | 8201.5 | 10550 |

S = vertical, L = horizontal, V = vee type; [1]) supercharged; [2]) = supercharged and with boost intercooling [3]) = with high boosting and boost intercooling.

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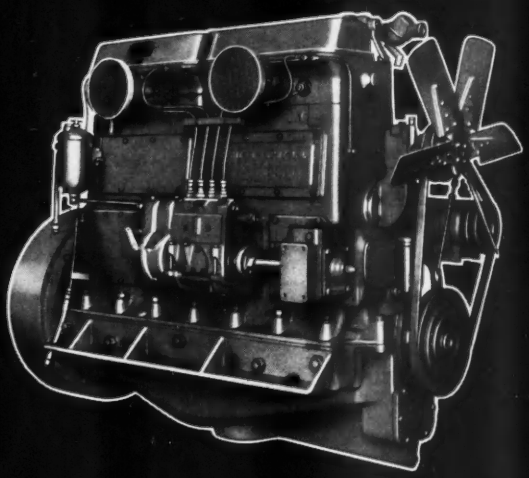

MERCEDES-BENZ DIESEL

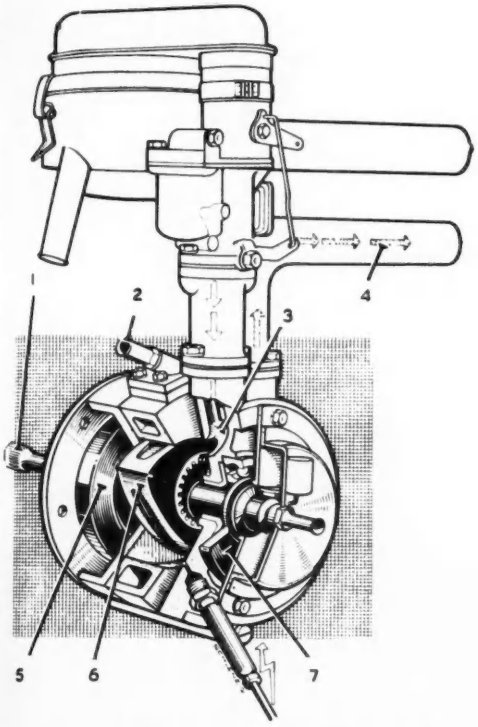


**Fig. 1. Cut-away view of the NSU-Wankel rotary engine.**
(1) Output shaft. (2) Cooling-water connection.
(3) Intake port. (4) Exhaust pipe.
(5) Flywheel. (6) Rotor.
(7) Balance weight.

of America, who have produced high-capacity versions which will shortly go into production for marine and aircraft applications.

The first rotary engine was tested in early 1957 and, after further experiments and development of the cooling system and sealing arrangements, a 125-cc engine was produced which developed 29 bhp at 17,000 rpm, and gave a specific fuel consumption of 230 grams/bhp-hr, with a mean effective pressure of more than 130 psi. This early engine consisted of an inner rotor, an outer rotor connected to the output shaft, and a casing around both rotors, the shape of the bore being epitrochoidal. A new and simpler engine has since been developed, in which the rotor shape remains unaltered and the bore contours are still epitrochoidal, but the bore is now stationary and, in fact, is integral with the casing.

In the new engine, only the rotor rotates, and its centre may be described as performing a circular orbit around the output-shaft centre, making it possible to drive the output shaft by means of a gear on the shaft and an annular gear attached to the rotor. This orbit is correctly maintained by the eccentric rotor bearings in the casing. Excessive bearing loads and/or vibrations are avoided because all rotating parts are fully balanced. Furthermore, it should be appreciated that the rotor revolves at only one-third of the speed of the output shaft, keeping inertia forces and surface speeds within manageable limits. A cut-away view of the engine is shown in Fig. 1.

The engine operates on the four-cycle principle, all four cycles taking place during a single revolution of the rotor, the sequence of operation being shown in Fig. 2. Thus, in position I, the induction volume (1) is at a minimum and is contained between the seals *A* and *C*. In position II, the exhaust phase is just about to commence as seal *C* uncovers the exhaust port, and the volume contained between seals *A* and *C* has only slightly increased. In position III, the exhaust and inlet are fully separated by seal *C*, and both the exhaust and the induction cycle are taking place. At the same time, the volume contained between seals *A* and *B* is at a minimum, and ignition takes place. Finally, in position IV, the volume contained between seals *A* and *B* is increasing, the distance from the output-shaft centre to seal *B* being greater than it is to seal *A*, so that the rotor rotates in a clockwise direction.

Initial tests on this 125-cc engine have shown that it can develop a power output of 29 bhp at 17,000 rpm, with a fuel consumption which is comparable with that of a 125-cc reciprocating piston engine. Furthermore, there is still an appreciable output under full load at the much lower speeds of 2500 and 1670 rpm. At present, the engine is water-cooled, but the possibility of using air cooling is by no means discounted.

The NSU-Wankel engine may be said to occupy a position between the reciprocating piston engine and the gas turbine, offering a degree of performance and economy which cannot be satisfied by either type over the wide range between them. The rotary engine, indeed, constitutes a challenge to the conventional piston engine,

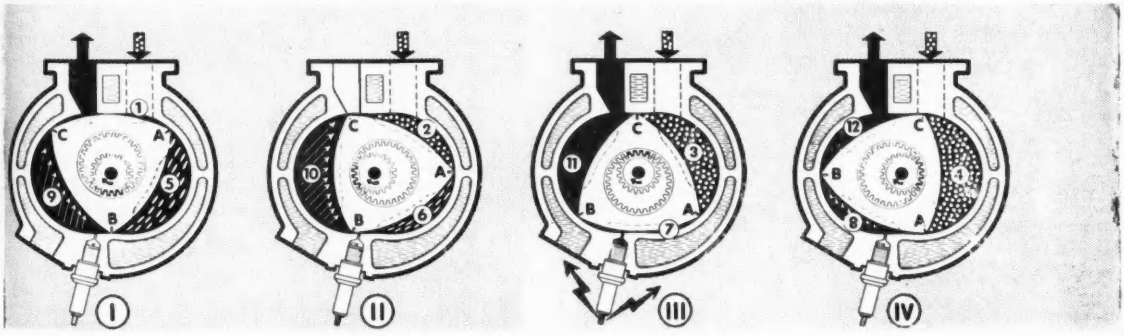


**Fig. 2. Sequence of operations during one revolution of the rotor.**
(1),(2),(3),(4)Induction. (5),(6),(7) Compression ignition. (8),(9),(10) Power stroke (combustion). (11),(12) Exhaust.

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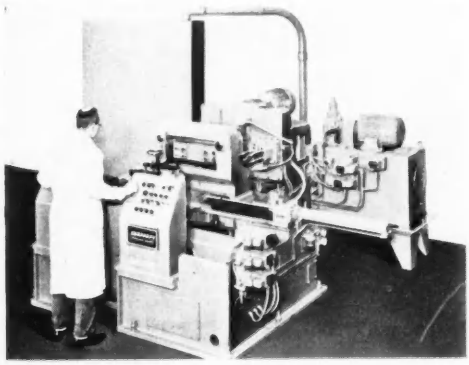
as it overcomes the latter's inherent speed limitations resulting from the inertia forces of the reciprocating masses. The cycle phases in the rotary engine are separated from one another, thus permitting high compression and expansion ratios, which are important factors in achieving economy of operation. Furthermore, its purely rotary motion and the complete absence of valve gear make the NSU-Wankel engine considerably less complicated and very much cheaper to produce than the reciprocating piston engine. Finally, it should be noted that its rotational speed can be controlled easily under maximum, as well as under part-load, conditions by means of a conventional accelerator pedal. whereas part-load operation is a demand which a gas turbine cannot easily satisfy.

## Automatic Special-Purpose Drilling, Chamfering, and Tapping Machine

Illustrating how the benefits of automation can be applied economically to low-production processes, a new machine, developed by the Buhr Machine Tool Company, of Ann Arbor, Michigan, is designed to carry out automatically the drilling, chamfering, and tapping of four holes on one side of lorry-flywheel housings, and then to perform similar operations on the other side, all with a



single hydraulic feed unit. For this purpose, the component is mounted on an indexing table, which is shuttled through the machine. After the holes on one side have been drilled, chamfered, and tapped, the table automatically indexes through 180 deg., and shuttles back to the first station, the same operations then being repeated on the other side. The machine, designated "Economatic", thus performs six sets of operations, although it has only three stations. Furthermore, although one hydraulic feed unit is used, drilling, chamfering, and tapping strokes are changed automatically. Because standard components are used in simple combinations, as in transfer machines, the machine can easily be converted to meet part-design changes or to process an entirely different part.

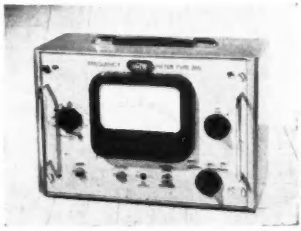
Workpieces are drilled in the same station, where they are manually loaded and clamped in a simple fixture. They are then successively positioned in the chamfering and tapping stations by movements of the shuttle. To accomplish rotation of the table after one set of holes is completed, an index pin is automatically withdrawn from the index table, which is then rotated through 180 deg. by a rack-driven slip-coupling. After rotation of the table, the index pin is re-engaged, and the shuttle returns against positive stops to the drilling station. The machining cycle is then repeated, the shuttle again carrying the workpiece past the tools. After withdrawal of the taps at the end of tapping operations, the table is rotated back to its initial position, and the shuttle returns the component to the load-unload station, the complete automatic cycle time being 108 sec. All movements of the machine are easily controlled by standard electro-mechanical units, using limit-switches and adjustable dogs. Movements are powered by hydraulic cylinders, and location is achieved by means of shot-pins or positive stops.

With the workpiece in any station, the hydraulic feed unit advances the tools rapidly. For drilling or chamfering, the feed rate drops to 5 ipm. Drills are fed in $1\frac{1}{2}$ in., but chamfering tools have a feed stroke of only $\frac{1}{4}$ in. When tapping is to be performed, the main hydraulic feed unit stops at the end of its rapid advance stroke, and the tapping units feed themselves. As a safety measure, taps cannot feed or rotate unless the shuttle is in the tapping station.

## Transistorized Frequency Meter and Tachometer

Fully transistorized, light, and portable, the new type-265 frequency meter announced by Airmec Limited, of High Wycombe, Bucks., can also be used as an electronic tachometer. For this reason, the large 5-in. meter used as an indicator is calibrated directly in both cps and rpm, accuracy being maintained by the provision of an internal highly stable frequency source which enables calibration of the instrument to be checked instantaneously.

The instrument, which can be operated by means of internal batteries or from an a.c. mains supply, can measure the frequency of a repetitive waveform in the range between 10 cps and 100 kcps with an accuracy of from $\pm 1$ to $\pm 2\%$. The input waveform is squared and limited, and is applied to an integrating circuit, and the circuitry is so arranged that the meter reading is independent of the amplitude or waveform of the input voltage. Input signals can be of any amplitude between 0·075 and 30 V r.m.s.



When used as a tachometer, all that is necessary is to arrange for the electrical pulses to be obtained from the moving member by means of a contact-breaker or a photocell and light source. However, the photo-electric method is naturally to be preferred, as it does not impose any loading on the equipment under test and is suitable for measuring extremely high rates of speed. Consequently, a special optical probe, containing a photocell and light source, is available for use with the meter for this purpose.

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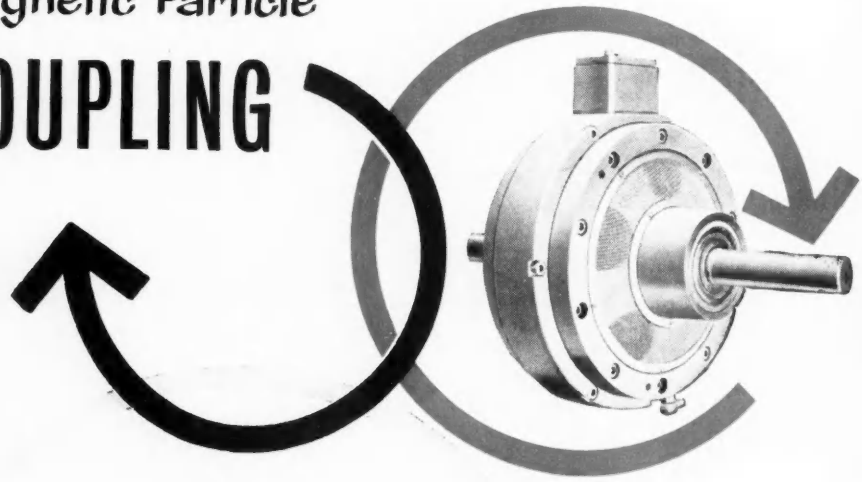

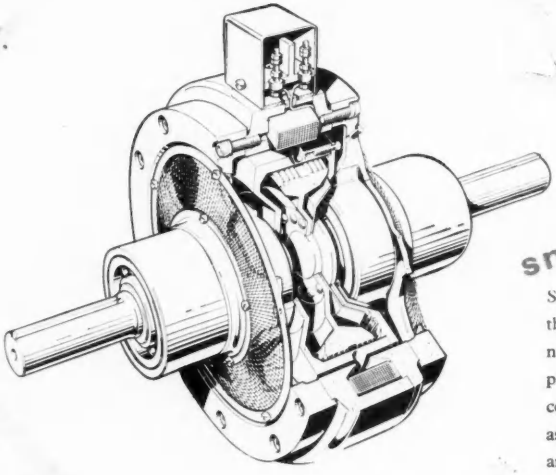

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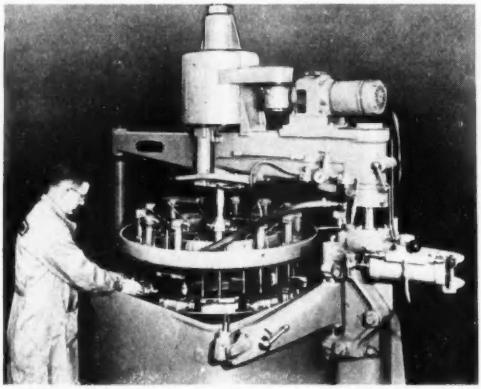
## Single- or Parallel-Face Flat Lapping Machine

Designed for either single- or parallel-face flat lapping, the new model No. 48 " Hyprolap " high-production lapping machine recently developed by the Norton Company, of Worcester, Mass., can be arranged for a plain timed cycle, for automatic continuous feed, or semi-automatic continuous feed. Special features of the design provide a means of handling a greater range of workpiece sizes at a more productive rate and with far less operator fatigue than have previously been possible, and also a better means of sizing control.

For single-face lapping, the machine mounts a single bonded abrasive-wheel lap, 48 in. in diameter, on a rigidly supported, heavy-duty vertical spindle, workpieces being retained in suitable adaptors, and proper lapping pressure secured through weights or pressure devices, as required. The truth of the lap face is generated and maintained by a rugged, column-mounted diamond truing-arm, operated hydraulically.



Opposed parallel flat faces can be lapped in this machine simultaneously. For this operation, a massive column and overarm arrangement is provided to support the upper 48-in. diameter lap. Workpieces are held in retainers between the two laps, and sizing is controlled by raising the lower lap with the company's " click-count " indexing-wheel feed arrangement and rotating full nut engaging a feedscrew. Both hand and power feed are provided.

The plain, timed cycle arrangement uses an electric timer to control the machine cycle. The operator merely removes finished parts, inserts rough parts, and then presses a push-button to start the cycle, which is terminated automatically by the timer. With the semi-automatic continuous feed arrangement, the operator removes finished parts and replaces them with new parts, as the lapping is effected continuously in a single pass through the laps. The automatic continuous feed arrangement eliminates the loading and unloading functions of the operator and places parts in automatic handling equipment.

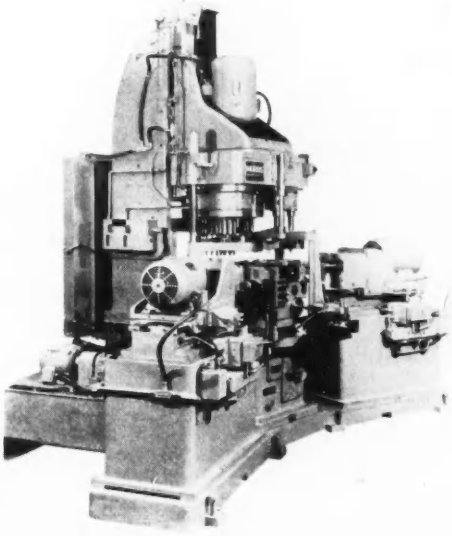
The bonded abrasive-wheel laps are used in conjunction with a filtered coolant. This combination results in many benefits such as a rapid lapping action with increased output, the production of finished parts ready for use, the elimination of costly washing operations, and the use of optical flats for inspection, owing to the bright surfaces produced. Individual adjustable-speed drives for both laps and for the workholder confer benefits in flexibility, providing speed combinations hitherto unavailable and making it possible to select the ideal combination for every workpiece.

## 26-Spindle Vertical Hydraulic Drilling Unit

Specially developed to perform 34 operations automatically on air compressors and capable of producing 180 parts per hour at 80% efficiency, a new high-production machine, designated Model 312-S, developed by The Morris Machine Tool Company, of Cincinnati, Ohio, uses a 26-spindle vertical way-type hydraulic drilling unit, with clusters operating at both the load and transfer positions of different stations.

The vertical-column indexing machine utilizes a table of 30 in. in diameter, with a 5-station automatic index, and incorporates an 18-in. way-type hydraulic slide unit mounted on the rear of the vertical column, as well as two 12-in. way-type units, supported on both the pedestal and platen, for horizontal operations at two of the stations. Each of these horizontal drilling units powers a 4-spindle head, one of the stations being used for a taper-reaming operation. The vertical and horizontal slide units are separately powered hydraulically, and their complete cycling can be predetermined and automatically controlled.

By cycling components twice around the table, substantial savings are achieved, as the number of drill units required is reduced. Double fixtures are used. Thus, with each indexing, the operator removes a completed component from the second position of the fixture, transfers a component from the first to the second position, and then loads an unfinished component into the first position, the cycle time being just over 16 sec. Other than loading and unloading, operation is completely automatic. Each of the standard drilling units has independent feeds and speeds, permitting adjustment without affecting the entire machine. When preset for correct alignment, the indivi-



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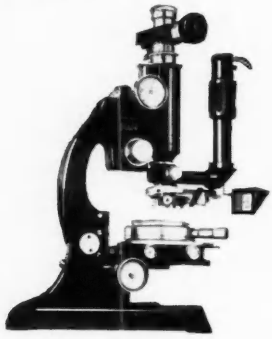

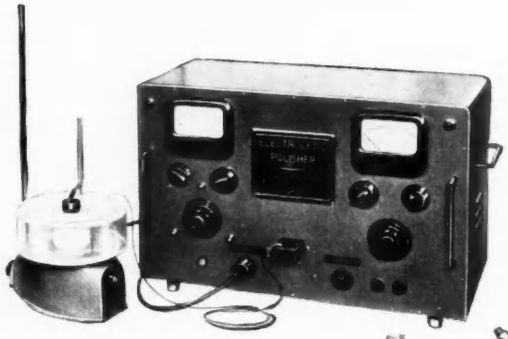

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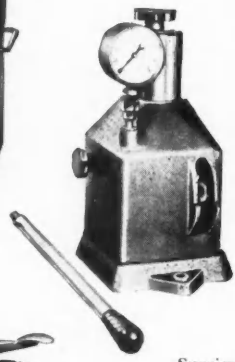

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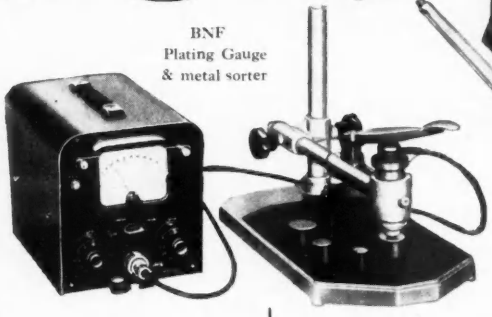

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dual unit performs the same operations each time the table indexes, all units being controlled simultaneously through an integrated electro-hydraulic system. Each multiple-spindle head is driven by an integral motor, assuring a perfect match between power source and load for maximum efficiency. If desired, the unit can readily be utilized to operate tool clusters at several stations of an indexing machine.

## Tape-Programmed Turret-Head Drilling Machine

Constructed by Vero Precision Engineering Ltd., of Southampton, and marketed by the sole selling agents, the Catmur Machine Tool Corporation, Ltd., of London, W.11, the Vero " Auto-Drill " is the world's first tape-programmed turret-head drilling machine with purely electrical control, and is also the first machine of its kind which is capable of drilling and tapping a pattern of up to 600 holes in six different sizes in any order without human intervention, this being achieved by controlling both the work position and the six-spindle turret head entirely automatically from a punched tape. The wide

range of drill sizes and spindle speeds provided, combined with the versatile control system used, enables this machine to be employed usefully in almost any light-engineering machine shop. Thus, on automatic control, its economic applications include the drilling of castings, plates, cabinets, printed circuits, etc., in any quantity from about twelve upwards. When manually controlled, it can speed up the production of components produced in smaller quantities and the manufacture of templates.

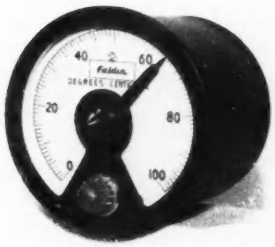
The drilling machine is fitted with a 32 × 9 in. co-ordinate table having a longitudinal traverse of 24 in. and a cross traverse of 12 in. The positioning speed is 60 ipm, and an overall drilling accuracy of ± 0·003 in. is guaranteed. The turret head is fitted with six chucks for accommodating drills of up to $\frac{1}{16}$ in. in diameter, and spindle speeds from 300 to 6000 rpm are provided. The maximum distance from the spindle to the table is 18 in.

The control system, which is manufactured by Airmec Limited, of High Wycombe, operates by measuring very accurately the total angular rotation of the leadscrews, a function performed by a positioner unit consisting of a series of commutator-type switches. Manual operation, if required, is performed from a control panel, and automatic drilling is controlled by a plastic tape carrying information for complete drilling or tapping operations. The outstanding feature of the control system is that it is purely electrical (rather than electronic) in nature, and routine maintenance can therefore be carried out by normal works electrical staff.

## Transistorized Temperature Controllers

The first of the new " Bikini " range of transistorized instruments announced by Fielden Electronics Limited, of Wythenshawe, Manchester, is a precision temperature controller with a differential of only 0·5°C, a high calibration accuracy, and a very high long-term stability. The instrument, which incorporates a completely transistorized electronic circuit of special design, operates from a 12-V d.c. supply, components functioning well below their maximum rating. Practically no heat is generated, there is no " warming-up " time, and only a light-duty type of cabling is required between the instrument and the power supply.

The instrument is housed in a small meter-type case and occupies a panel space of only 4½ in. diameter. The scale, 9 in. in length, is calibrated directly in °C or °F, and the pointer is set to the required control temperature by a small knob. Control action is indicated by a red lamp, which is visible from the sides and front of the instrument. The case is completely sealed and contains no galvanometers, pivots, or other delicate moving parts, and the instrument can be mounted at any angle. Control can be effected at any temperature between — 200°C and + 500°C, with a minimum temperature-range span of 50°C, and twelve standard calibrations in °C or °F are available.




A platinum resistance element is used at the temperature measuring point, this being housed in a robust stainless-steel sheath of ¼ in. diameter. Ordinary connecting cable is used between the measuring point and the instrument and can be up to 300 ft in length without introducing errors. Control action, of the on/off type, can be either electrical or pneumatic, the electrical contacts giving change-over switching at 250 V, 5 A, while the pneumatic valve requires from 17 to 20 psi input. An interesting feature is that the electrical or pneumatic control relay can also be located up to 300 ft away from the instrument itself, suing simple light-duty connecting cable.

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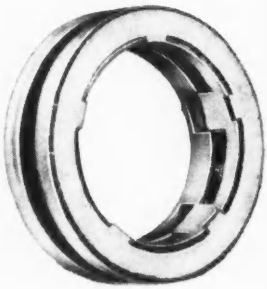

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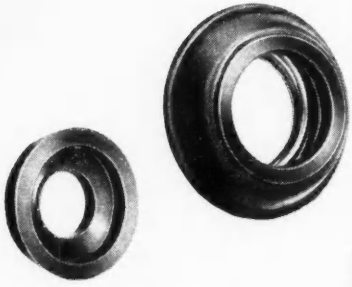

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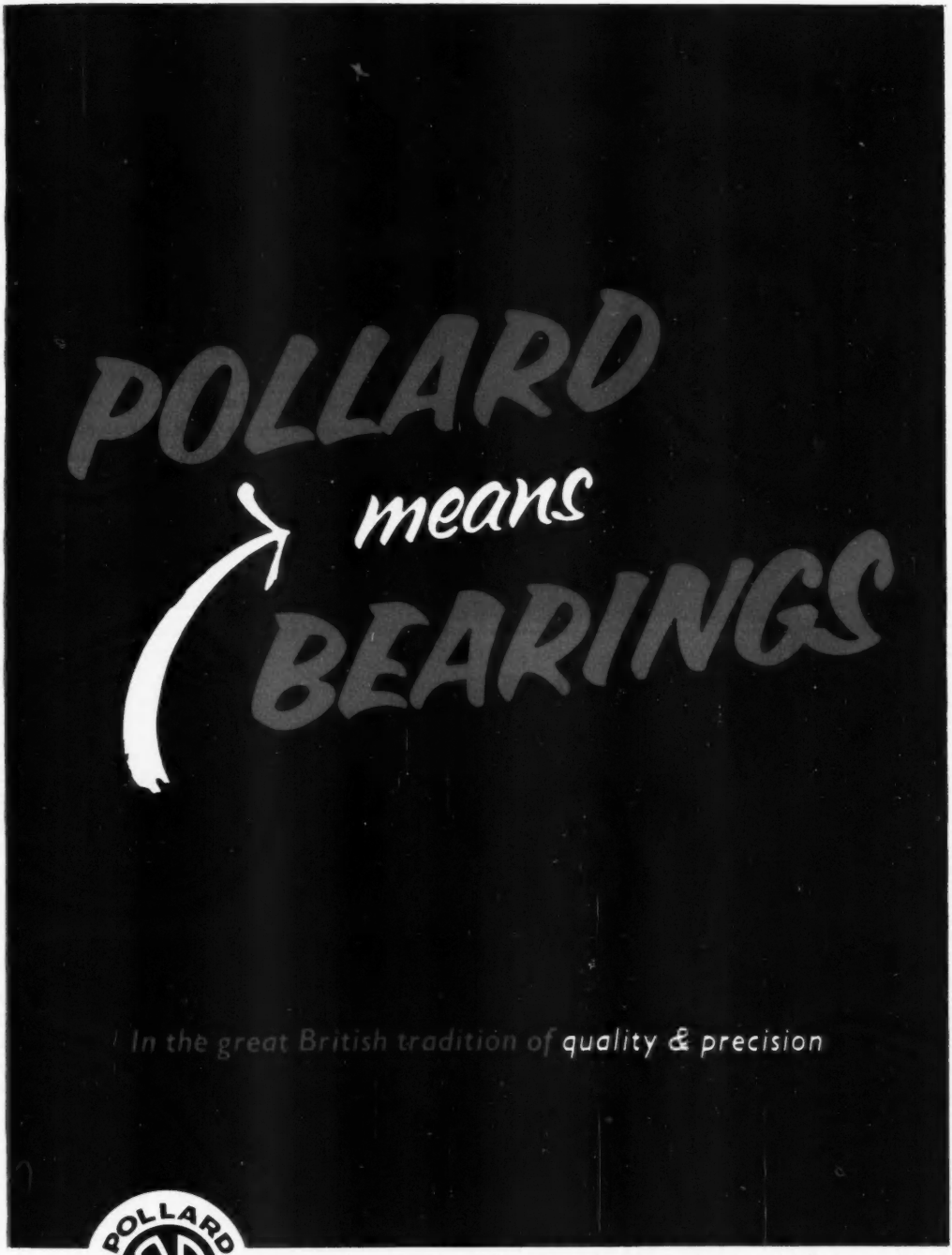


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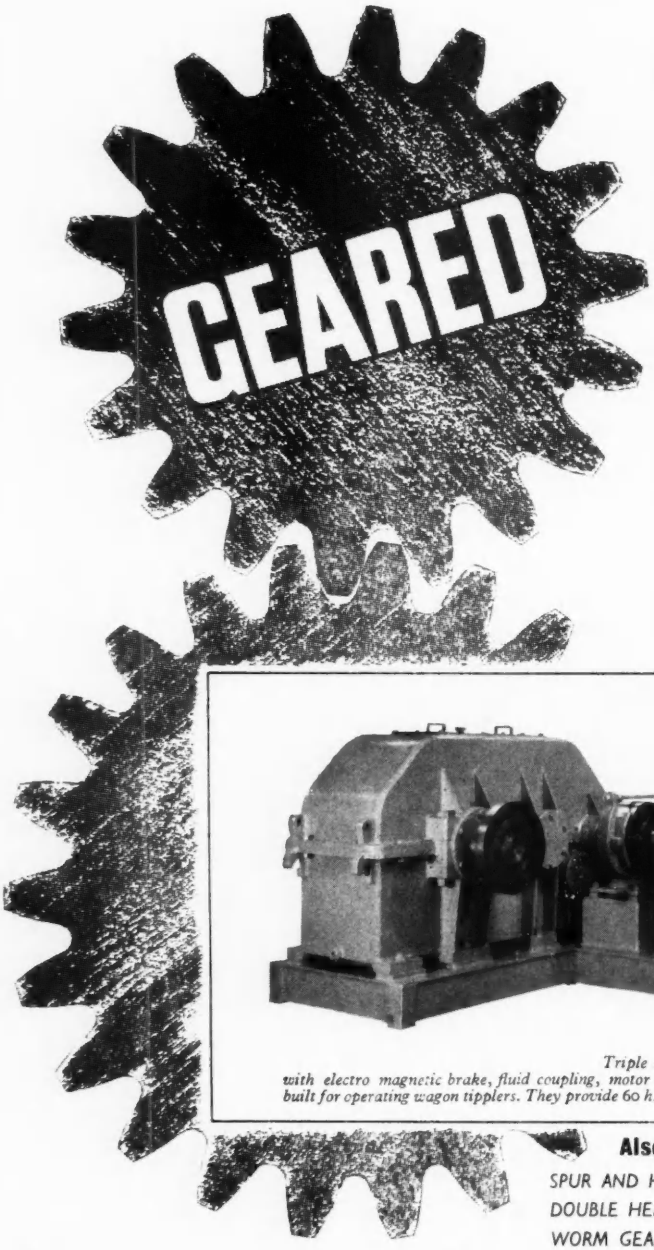


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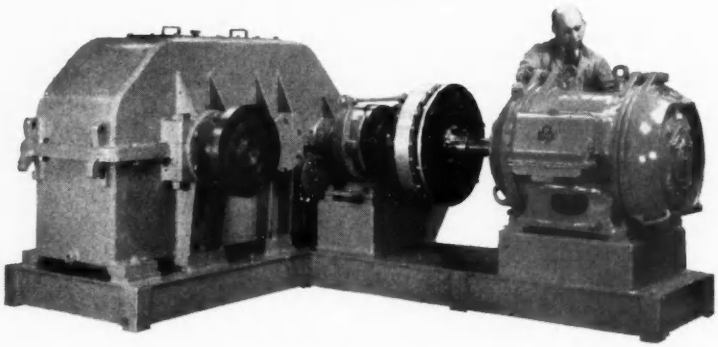

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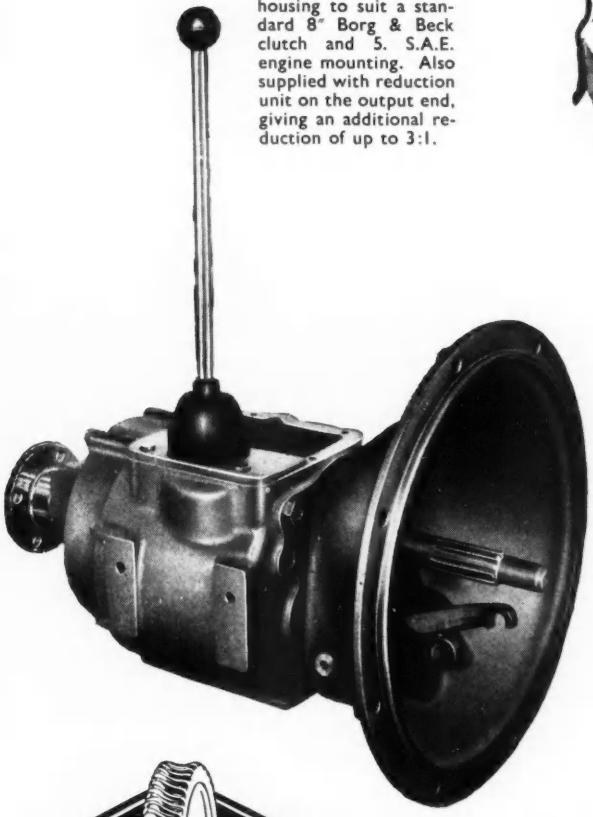

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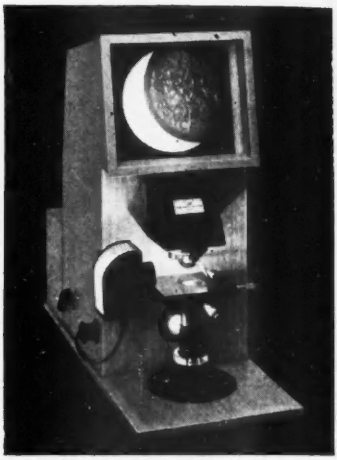

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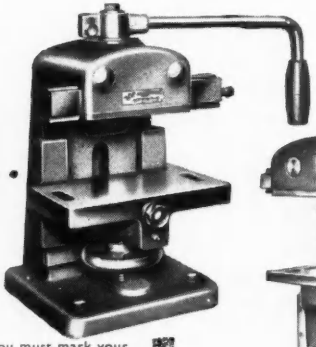

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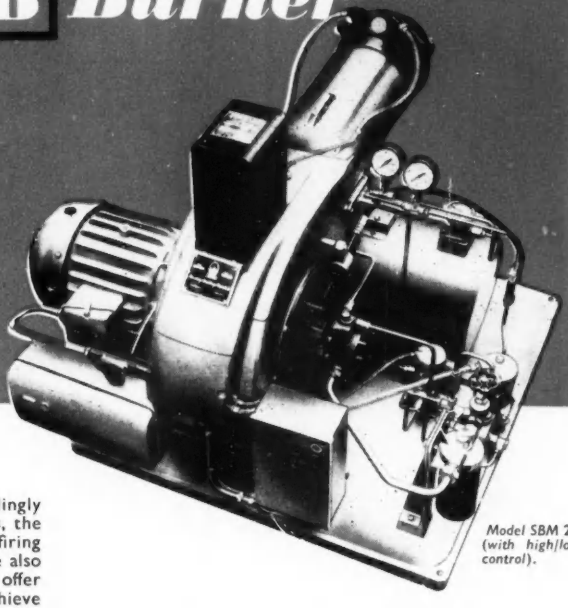


*Model SBM 25H/L (with high/low/off control).*

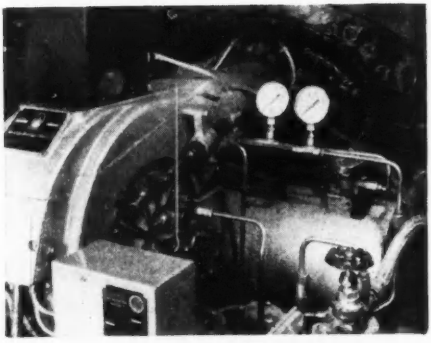
Developed from the Model ZH, Nu-way's outstandingly successful series of fully automatic commercial burners, the new SB models are primarily intended for the efficient firing of steam boilers at lower capital cost. SB burners are also particularly suitable for firing any other boilers which offer high resistance to the flow of combustion gases. To achieve this the fan pressure on the SB design has been substantially increased to produce a convergent air blast at the nozzle which is strong enough to play a significant part in atomising the oil and promoting rapidly completed combustion. The resulting flue gas velocity is high enough to overcome very substantial boiler and flue resistance which would cause ordinary burners to pulsate and smoke.

One important advantage of this new atomising system is that the combustion chamber volume required for a given rate of firing is greatly reduced. Vertical boilers fired with the SB burners can usually accommodate a fire-box of sufficient size without excavation or extending the boiler skirt, thus lowering installation costs and speeding installation time.

SB burners can be applied to shell-type boilers, their combustion efficiency and cost of installation comparing most favourably with other more cumbersome oil-firing systems.

These new burners are now being produced in a wide range of sizes for different grades of fuel. The various groups are: Model SBL, for light distillate oils and Models SBM and SBH for medium and heavy fuel oils respectively.

All but the smallest SB burners can be supplied with Nu-way High/Low/Off control. This high/low flame equipment which is standard on all larger SB Models gives appreciable fuel savings, inhibits pulsation on light-up and stabilizes steam pressure.



*Close up of a typical SB burner application. Showing a Model SB17 H/L burner firing a Cochran boiler of 1500 lb./hr. evaporation, through the former stoking door. Note the ram-operated high/low air control on the fan inlet.*

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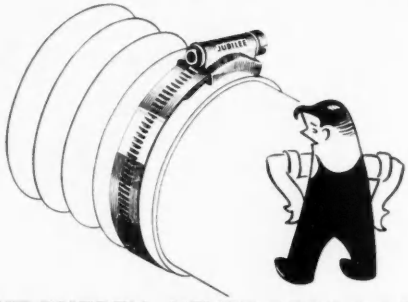

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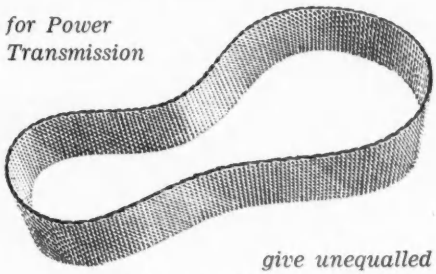

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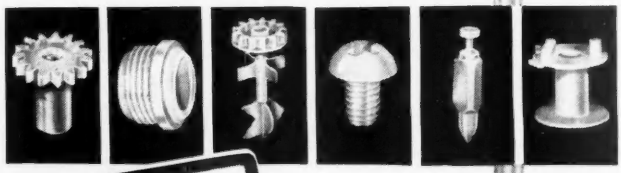

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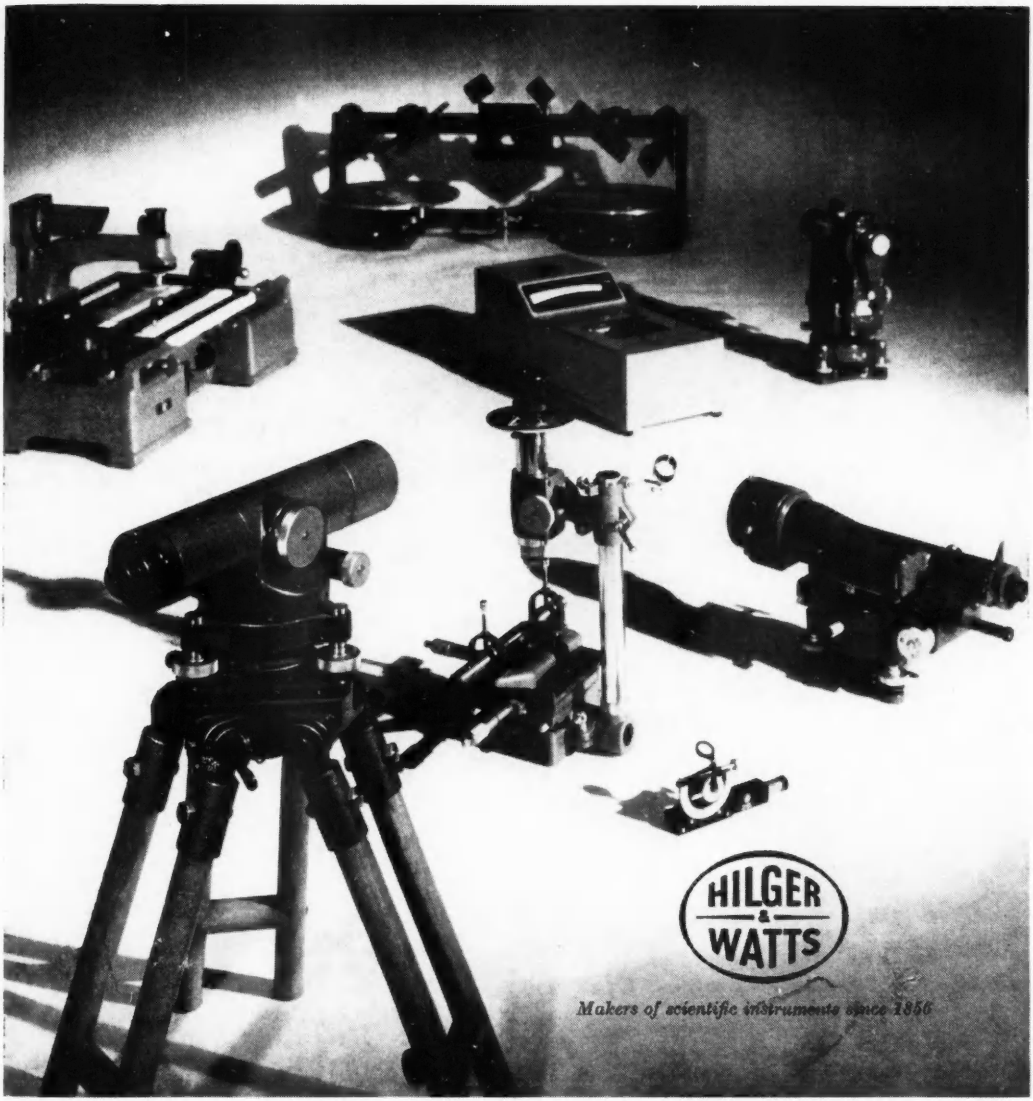


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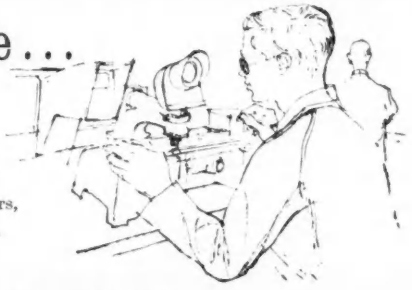

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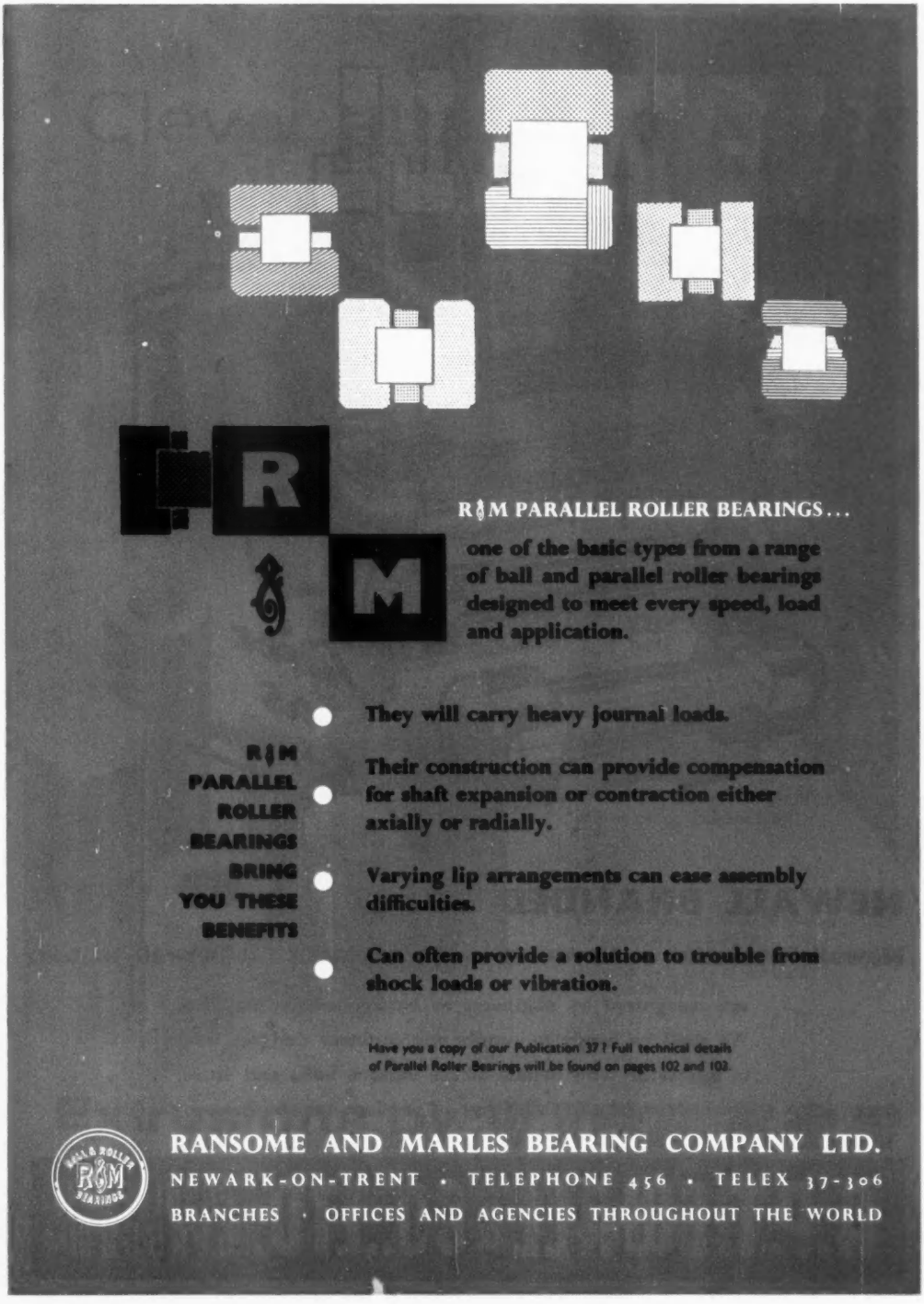
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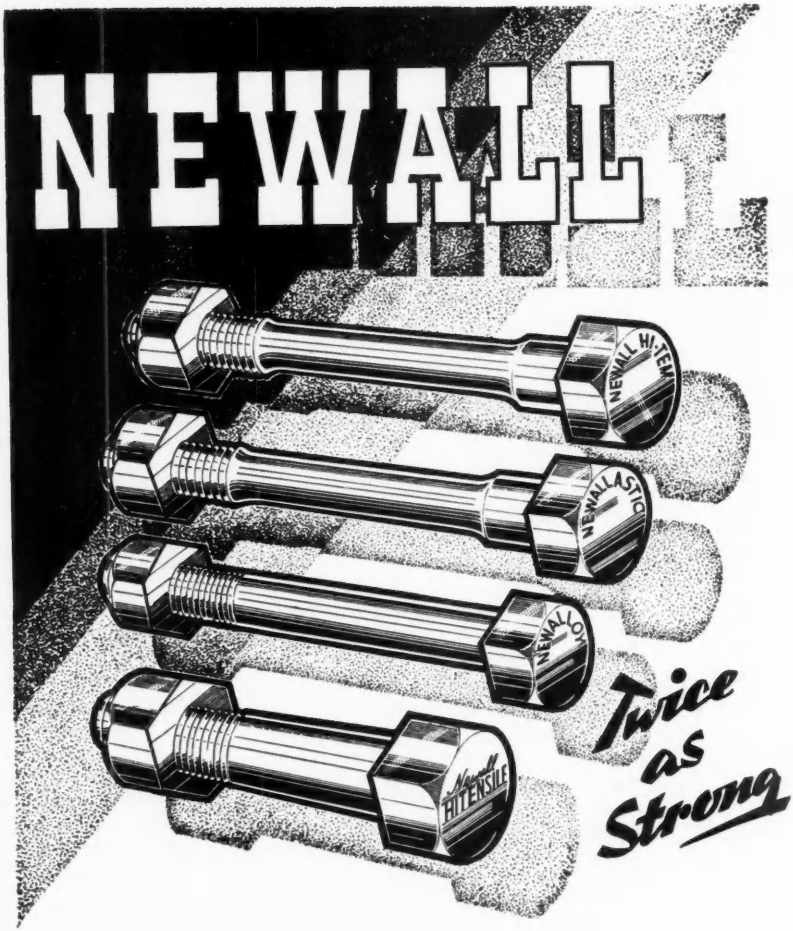


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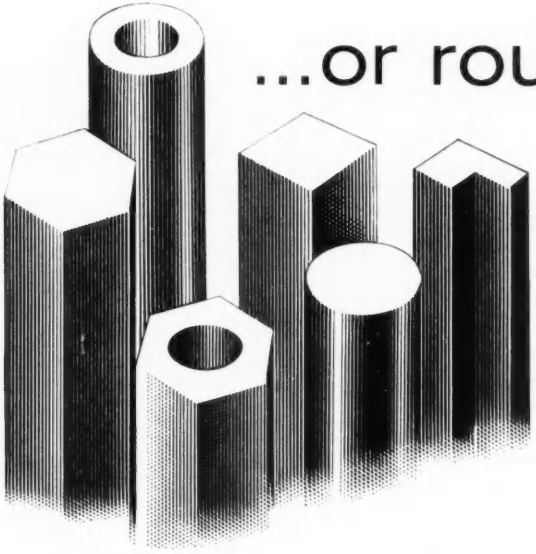

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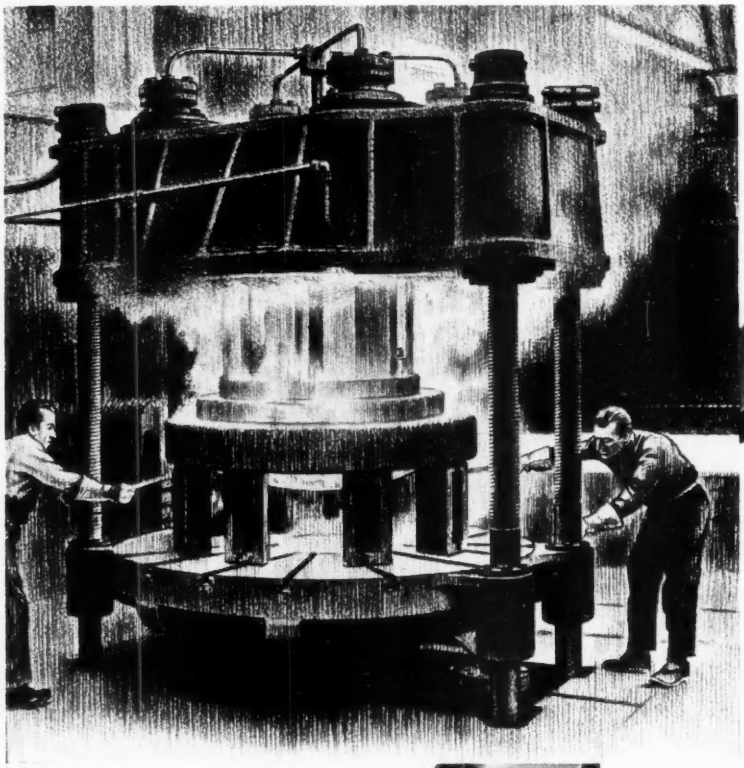
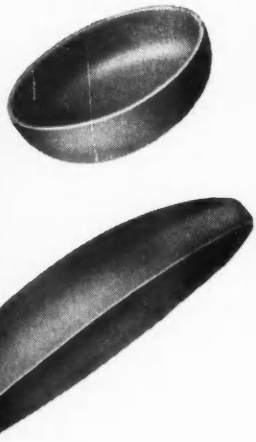
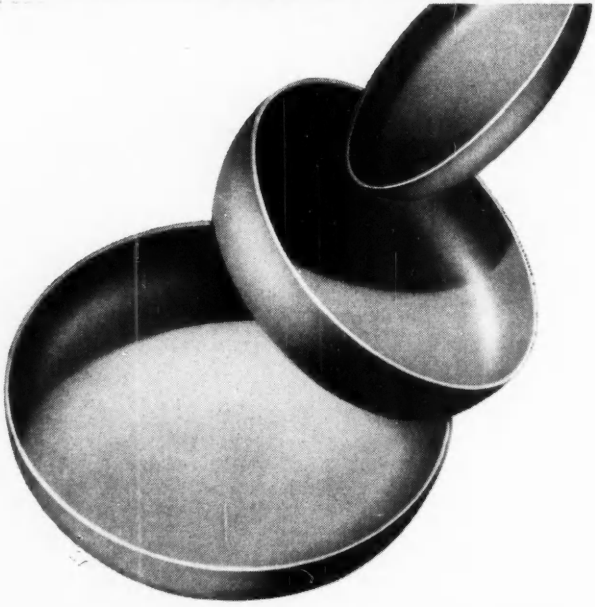




# DISHED and FLANGED ENDS



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SEMI-ELLIPSOIDAL HEADS can be produced on the Rotarpress ; diameters 5 ft. to 15 ft. ; thicknesses $\frac{3}{8}$ in. to 4 in.

*For details, please ask for List No. ED 965.*

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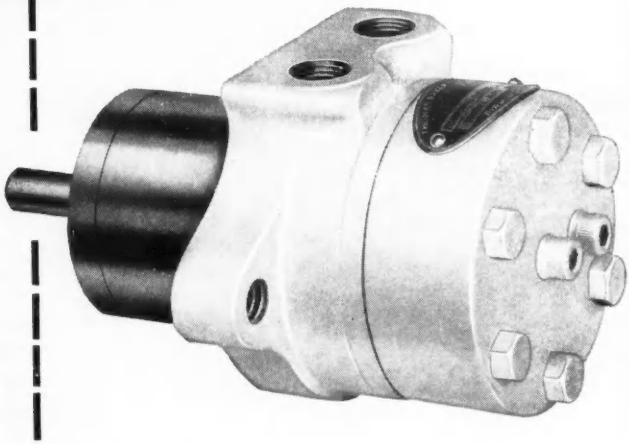

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. . . . and the secret is buying the best! Only the highest grade Chrome Vanadium Swedish Steel is used by DART and this is carefully heat treated to ensure top quality performance. All springs are shot peened to combat fatigue and thoroughly tested by scragging solid. Finished by an approved phosphate process to prevent rusting, Die Springs by DART are made in 28 sizes, always in stock. Write or 'phone (Dept. S.M.O.) for our latest price list.

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The **DART SPRING** Co. Ltd. **WEST BROMWICH**

## multi-spindle drilling attachments

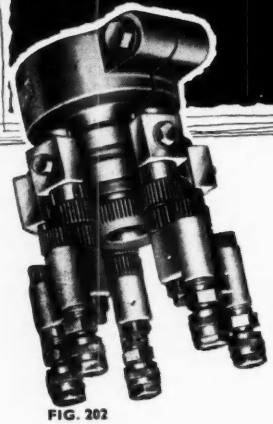


FIG. 202

## multi-spindle tapping attachments

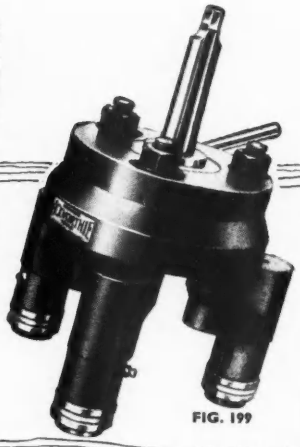


FIG. 199

Multi Spindle Drilling—Multi Spindle Tapping, 2 Spindles to 20—fully adjustable or fixed. Send today for your copy of "Automation by Ackworthie/C"

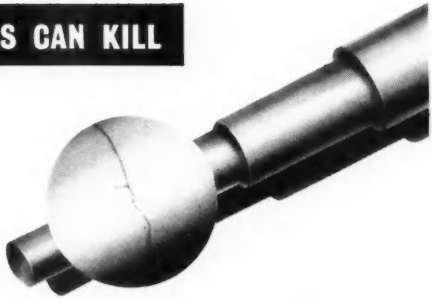
Illustrated Ackworthie Multi Spindle Drilling attachments Fig. 202 and Fig. 199 designed to give a wide range of Spindle adjustment. Special Machines built to customers' requirements.

**ACKWORTHIE**

**JOHN ACKWORTHIE LTD**
**Dalehouse Lane, Kenilworth, Warwickshire**
*Telephone: Kenilworth 1530 (P.B.X.)*

## SURFACE CRACKS CAN KILL

### *Can* **YOU** *rely on the naked eye?*

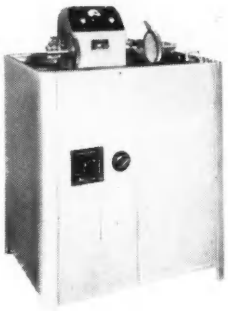


Yes—if there's something for the eye to see. And there always is when a FEL-ELECTRIC Magnetic Crack Detector is used. Surface cracks, and in some cases sub-surface cracks, are shown up clearly with the aid of FELTEC Detector inks.

Any size or type of component can be thoroughly tested by a Fel-Electric Crack Detector. The machine is easily operated, speedy and completely non-destructive to the component under test.

Fel-Electric design and supply detectors for any type of component—even very large items which must be tested in situ.

If you have an inspection problem or would like more technical details, please write or telephone.



**To show these faults the Detector used was our Model LB.126 which employs the AC Current Flow method and operates on a Time Control immersion principle. It is suitable for testing parts from 1" to 16" long.**

★ ***FELTEC Crack Detector Inks are supplied in Black, Red, Yellow, White and Fluorescent***

*Ferrous and Non-Ferrous Crack Detection by*

## FEL-ELECTRIC LIMITED

**Sydney Street, Sheffield, 1. Tel: 27357**

CONTRACTORS TO H.M. ADMIRALTY, AIR MINISTRY, MINISTRY OF SUPPLY

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*For heat treatment in laboratory and workshop*

An *A.E.W.*

## ELECTRIC FURNACE

of ADVANCED DESIGN

**★ High Efficiency ★ Rapid Heating ★ Longer Life**

Developments in the chamber insulation of A.E.W Furnaces enable the working temperature to be reached quicker and evenly maintained throughout the chamber. To further prevent heat losses the drop-down door is also efficiently heat sealed.

The elements are carried in interlocking refractory bars which allow free expansion and contraction without mechanical strain thus ensuring a longer life.

All A.E.W. Furnaces are designed and manufactured by specialists and you are invited to write for full technical details to

**A.E.W. LTD.**

**Imperial Works, High St,, Edgware, Middx.**

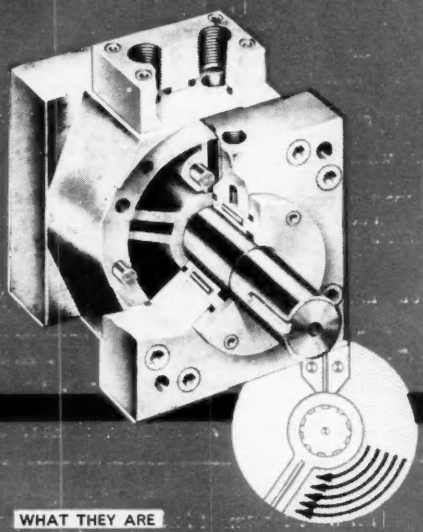
Telephone: Edgware 5278 (3 lines)

AEW

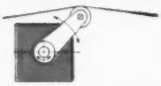
**KEELAVITE**
Hydraulics

# ROTARY TORQUE ACTUATORS (ROTAC)

give highest torque in least space



STRAIGHT LINE MOTION— DOUBLE TRAVEL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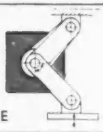
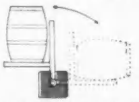

TOGGLE

HIGH TORQUE RATCHET DRIVE

DUMPING OR TUMBLING


ROLL OVER OR UPENDING

TURN OR OSCILLATE

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## WHAT THEY ARE

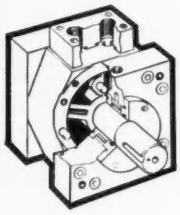
Keelavite/Rotac units are operated hydraulically at low to medium pressures, developing instant torque in either direction. For single vane units the motion is limited to a maximum arc of 280 degrees by the fixed shoe within the cylinder. Power can be doubled by the use of two vanes. In this case the arc of travel is 100 degrees.

## WHY THEY ARE BETTER

Torque actuators provide high power in a small space with simple mountings. They can replace other types of actuators, such as cylinders, which require complicated linkage to perform the same functions. In hydraulic systems torque actuators are an ideal solution to many complex mechanical problems.

## TYPICAL USES

Opening and closing valves.
Opening and closing doors.
Automation and machine tool uses including:
indexing, feeding, transferring, clamping, locating, turning over.
Freight car tippling.
Crane boom operation.
Pipe and tube bending.
Fatigue test applications.
Foundry equipment.
Materials handling and control of movement on conveyors.



1. *Choice of mountings for fixing at any angle in any position.*
2. *Effective sealing means no oil leak therefore positive control of shaft rotation.*
3. *Working mechanism fully sealed from dirt.*

*Keelavite/Rotac rotary actuators are manufactured in the United Kingdom under licence from the* XLO *Corporation*

THE RECOGNISED AUTHORITY

*For full details write to*

**KEELAVITE**
Hydraulics

**KEELAVITE HYDRAULICS LTD**
ALLESLEY. COVENTRY. TEL: MERIDEN 441

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